TAXONOMY AND DISTRIBUTION OF RECENT FORAMINIFERA FROM DWARKA BEACH, SAURASHTRA COAST, GUJARAT

DISSERTATION SUBMITTED IN PARTIAL FULFILMENT
OF THE REQUIREMENTS FOR THE DEGREE OF
MASTER OF PHILOSOPHY IN GEOLOGY

BY

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D E D I C A T E D

TO

MY UNCLE MR. M. AYYOUB FAROOQUI

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DR. ABU TALIB
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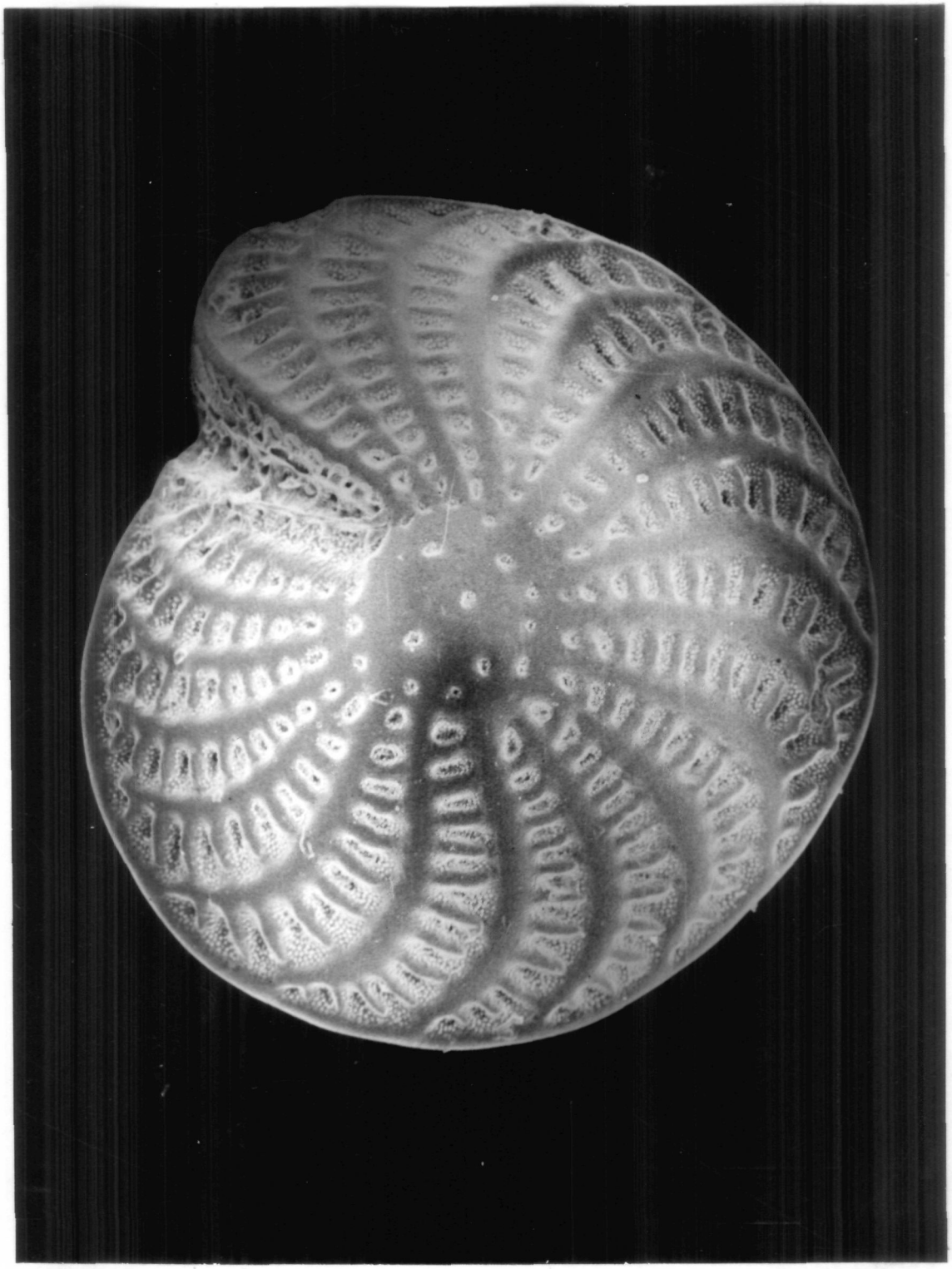
This is to certify that Mr. M. Yusuf Farooqui has completed his research under my supervision for the degree of Master of Philosophy of Aligarh Muslim University. This work is an original contribution to our knowledge of the taxonomy and distribution of Recent foraminifera from Dwarka beach, Saurashtra Coast, Gujarat, and has not been published anywhere.

He is allowed to submit the work for the M.Phil. degree of Aligarh Muslim University, Aligarh.

(Abu Talib) 22/2/91
SUPERVISOR



Elphidium crispum (Linnaeus)
Dwarka beach, Gujarat
Stereoscan micrograph X175

A C K N O W L E D G E M E N T

I owe a great debt of gratitude to my supervisor Dr. Abu Talib, Lecturer, Department of Geology, Aligarh Muslim University, Aligarh for selecting the problem for my M. Phill. dissertation and giving the much needed guidance during the entire course of the present study. I am also thankful to him for providing valuable literature from his personal collection.

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(M. Yusuf Farooqui)

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C H A P T E R - I

INTRODUCTION

1.1 Aim and Scope of Study

The law of uniformitarianism "the present is the key to the past" stands as one of the basic principles of geology. Most of the interpretations regarding ancient geological processes and phenomena are based on this principle, including reconstruction of past environments.

Amongst marine microorganisms, foraminifers are globally recognised as excellent indicators of Recent and geologically past environments. Extensive researches on foraminifera have proved the significance of this group of microfossil in age determination and correlation of strata, delineation of paleobiofacies and paleogeography as well as interpretation of tectonic history of basin.

It is well known that organisms live in perfect equilibrium with their environment and many fossil organisms resemble their living counterparts in many ways such as form, composition, habit, etc. Therefore, the ecological data obtained from living forms are useful in the interpretation of paleoecology. Foraminifers are highly sensitive to environmental changes and that is why, in order to reconstruct a precise picture of past environments, Recent

foraminifera are receiving considerable attention from micropaleontologists all over the world.

The study of foraminifera has contributed significantly in the exploration of oil and gas in various parts of the world and after the discovery of oil and gas in off shore Cenozoic strata of India, the importance of Recent foraminiferal studies along Indian coastline has increased manifold.

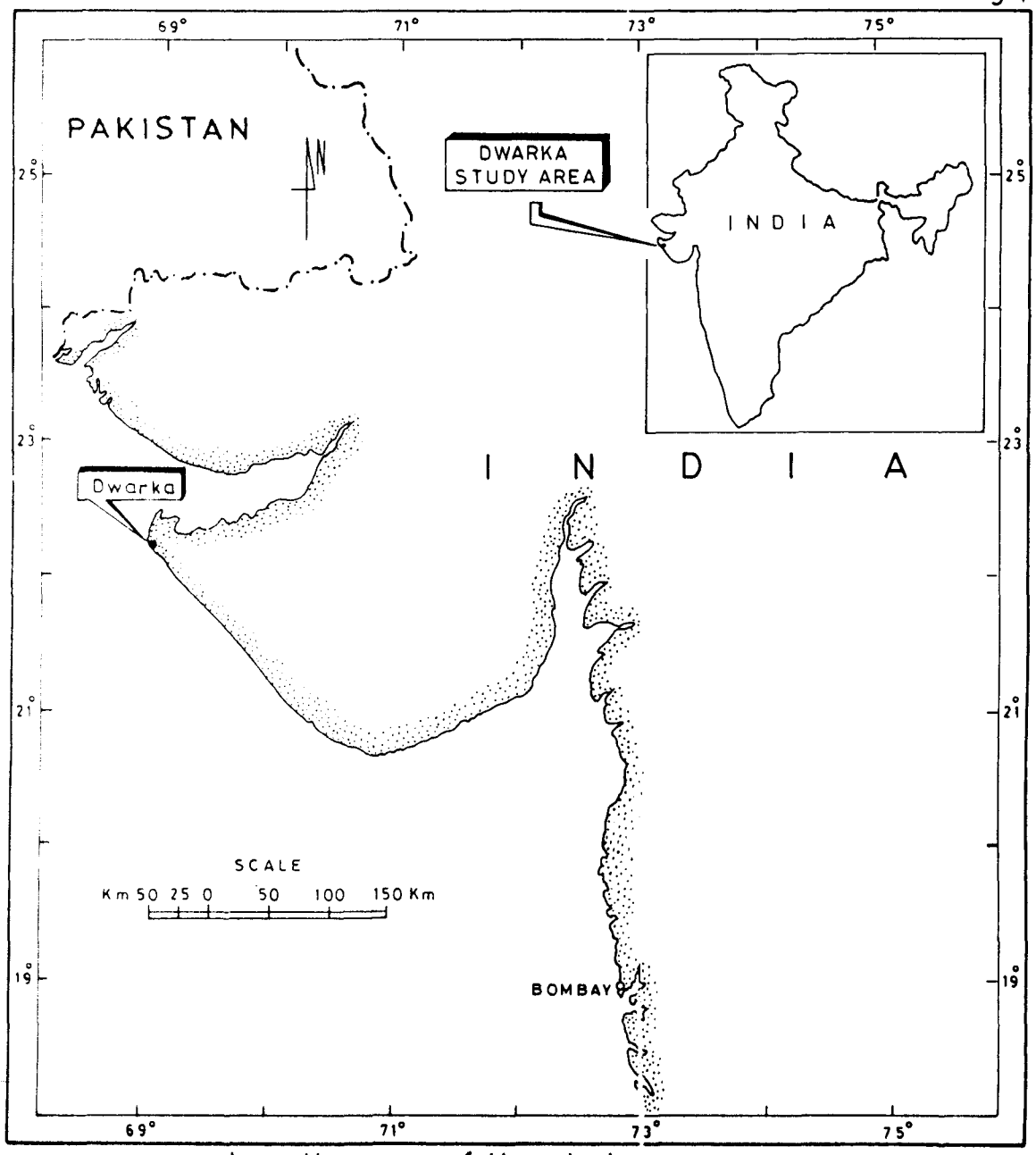
A survey of literature reveals that although a large number of publications exist on Recent foraminifera of different parts of Indian coastline but little has been published on the Recent foraminifera from Saurashtra Coast. The only records of Recent foraminifera from this region are by Bhatia (1956), Rocha and Ubaldo (1964a), Srivastava et al. (1984) and Bhalla and Lal (1985).

Therefore, in order to acquire a deep knowledge of taxonomy and distribution as well as ecology of Recent foraminifera along Saurashtra Coast, extensive studies are required. The present investigation is an effort in this direction.

The present study will contribute towards a better understanding of taxonomy and distribution of Recent foraminifera in the Arabian Sea region, specially along Saurashtra Coast. The ecological data furnished by the

Text - fig. 1

Text-fig.1



Location map of the study area

present study may be helpful in paleoecological interpretations.

The present investigation may also be helpful in deciding whether the East and West Coasts of India belong to the same or different foramgeographic province as controversy still exists in this regard.

1.2 Location of Study Area

The study area comprises a beach located near Dwarka (Latitude, 22°14'; Longitude, 68°58') in Gujarat State (Text-fig.1). It is a part of the Saurashtra coastline which forms the northernmost portion of the West Coast of India. Dwarka beach is one of the prominent sandy beaches of the Saurashtra Coast and is included in Dwarka Mandal Taluka of Jamnagar district of Gujarat.

Dwarka has a long historical background. A famous sacred town, Dwarka is situated 145 km west of Jamnagar district. It is one of the chief centres of Krishna legend and is a sacred centre of Hinduism.

Archaeological excavations show that present day Dwarka is the sixth city on this site. Dwarka is connected with Jamnagar by regular state bus services and metergauge railways.

C H A P T E R - I I

ENVIRONMENT OF STUDY AREA

2.1 Physiography and Bathymetry

The shoreline of Dwarka is remarkably straight and has an emergent aspect. It is a shore adjoining a low-level plain tract with an extremely gentle offshore profile. A zone of sand dunes is found along the coast of Dwarka. Occasionally there is a series of two to three parallel beach ridges, 10 to 20 m high, and extending for several kilometers at a stretch.

Coastal zone is variable in Saurashtra region. However, along the Dwarka Coast it is about 20-30 km inland. Shorewards the coastal margin between Diu and Dwarka adjoins narrow beach ridges. Near Dwarka clay and Foraminifer limestone, collectively known as Dwarka beds (Oligocene to Pliocene), are found which are underlain by clays containing gypsum.

The most striking feature on the western part of Saurashtra is, a little raised above sea level, the "Littoral Concrete" deposit which is an agglutinated shelly grit composed of shells, corals, pebbles and sand cemented together, more or less thoroughly by carbonate of lime and sufficiently compact at some places to be employed as an

inferior kind of building stone. Age of this Littoral Concrete is sub-Recent to Recent.

The Littoral Concrete occurs as rocky beach either directly attached to the mainland or separated from the latter by zone of sandy beach and marshy area. One river, locally called Gomti, joins the Arabian Sea just behind Sangam Narayan temple located near the southern end of Dwarka beach.

The submarine contours run more or less parallel from Dwarka to Veraval along Saurashtra Coast. The gradient is gentle (10 km/10 m depth) from 0 to 76 m submarine contour whereas it is rather steep (6 km/10 m depth) from 76 to 150 m submarine contour. The distance of the nearest 76 m submarine contour from Dwarka is about 72 km.

2.2 Characteristic of Dwarka Beach Material

Microscopic examination of beach material reveals that it is slaty grey and brown in colour, mainly composed of coarse sand grains. The average mean grain size of Dwarka beach sand ranges between 275 μ to 291.5 μ.

The sand grains consist of mainly angular to sub-rounded quartz alongwith entire as well as broken shells of ostracodes, molluscs, foraminifers, etc., and they are well to very well sorted. In addition, heavy minerals such as

muscovite, limonite, garnet, ilmenite, zircon, actinolite, tourmaline, etc., are found.

2.3 Climate

Climate of Dwarka is generally pleasant throughout the year. Cycle of seasons consists of summer from March to mid June and winter from December to February. Monsoon generally commences in the second week of June and exists till the end of October. This is followed by autumn season which lasts for a relatively short period from late September to early November.

Relative humidity is about 80% during full monsoon and about 60 to 75% during rest of the year. Moderate to heavy clouds prevail during the monsoon season while sky is clear or with thin clouds during the remaining months of the year.

C H A P T E R - III

PREVIOUS INVESTIGATIONS AND METHODOLGY

3.1 Previous Researches

Early records of Recent foraminifera from the Indian coast are by Parker and Jones (1865) and John Murray (1889). A survey of literature reveals that although a fairly large amount of work now exists on the Recent foraminifera of different parts of the Indian coastline little has been published on Saurashtra Coast.

Kurian (1951) was probably first to study the Recent foraminifera from West Coast of India followed by Chaudhury and Biswas (1954), Bhatia (1956), Sethulakshmi Amma (1958), Rocha and Ubaldo (1964a, b), Chatterjee and Gururaja (1967), Antony (1968), Kameswara Rao (1970a, b; 1971 a,b), Siebold (1971, 75), Rao and Rao (1974), Bhatia and Kumar (1976), Jain and Bhatia (1978), Bhalla and Nigam (1979), Bhalla and Raghav (1980), Srivastava et al. (1984), Bhalla and Lal (1985), Bhalla and Gaur (1987), and Shareef and Venkatachalapathy (1988). From East Coast, Recent foraminifers were recorded by Ganapati and Satyavati (1958), Ganapati and Sarojini (1959), Bhatia and Bhalla (1959), Ghose (1966), Rao and Vedantam (1968), Bhalla (1968, 70), Vedantam and Rao (1970), Rao and Rao (1971, 74), Rasheed and Ragothaman

(1978), Ragothaman and Kumar (1985), Ragothaman and Manivannan (1985), and Naidu et al. (1985).

However, as far as only beach fauna from West Coast of India is concerned, first of all it was Chaudhury and Biswas (1954) who studied twelve species of perforate foraminifera from Juhu beach sand near Bombay. Bhatia (1956) described forty-six species of foraminifera from Bhogat beach, Gujarat as well as Chowpatty and Juhu beaches of Bombay. He was followed by Rocha and Ubaldo (1964 a, b) who reported fifty-two species of Recent foraminifera from Diu, Gogola and Simbor beaches, twenty-five species from Baga (Goa) beach, and nine species from Jampore (Damao) beach sands. Jain and Bhatia (1978) described thirty-seven foraminiferal species from Mandvi beach, kutch including a new species, viz., Pararotalia boltovskoyi. Bhalla and Nigam (1979) reported thirty-six species of Recent foraminifera from Calangute beach sand (Goa), Bhalla and Raghav (1980) described twenty-five species of Recent foraminifera from Cochin, Chellanam and Purakkad beaches of Malabar Coast. According to these authors the distribution of Recent foraminifera in the beaches of Malabar Coast is mainly controlled by ecological factors in which salinity plays a dominant role. Bhalla and Gaur (1986, 87) described twenty-nine species of Recent foraminifera from Colva beach sand (Goa). Shareef and Venkatachalapathy (1988) recorded forty

species of Recent foraminifera from Bhatkal area and forty-one species from Devgad island (Karnatak), West Coast of India .

However, the only publications of Recent foraminifera of Saurashtra Coast are by Bhatia (1956), Rocha and Ubaldo (1964 a), Srivastava et al. (1984), and Bhalla and Lal (1985).

Bhatia (1956) described thirty species of Recent foraminifera from beach sand of Bhogat, Gujarat. The foraminiferal assemblage is dominated by the genus Streblus and majority of the species are characteristic Indo-Pacific forms.

Rocha and Ubaldo (1964 a) reported thirty-four species of Recent foraminifera from Diu, thirty-nine species from Gogola and twenty-nine species from Simbor beach. The foraminiferal assemblages of Diu, Gogola and Simbor beaches are dominated by Streblus taiwanica, Streblus annectens, and Streblus papillosus and belong to warm and temperate shallow water region. However, there is an absence of agglutinated forms suggesting weak terrigenous sedimentation.

Srivastava et al. (1984) reported twenty-seven species of Recent foraminifera from beach sands of Veraval, Gujarat, belonging to eleven genera and eight families, out of which twenty-six species are benthonic and one planktonic.

According to Srivastava et al. (1984) the fauna from Veraval coast may be assigned to a near shore shelf zone environment, highly affected by surf action which has produced smooth, rounded, and polished tests. These authors also observed that faunal elements exhibit high frequency but low variability and there is a total absence of agglutinated tests.

Bhalla and Lal (1985) reported an assemblage comprising eighteen species of Recent foraminifera from Okha beach sands, Saurashtra Coast. According to Bhalla and Lal (1985) all the foraminiferal species from Okha beach are benthonic in nature and belong to warm water environment.

3.2 Methodology

3.2.1 Field method

The material used in the present study was collected from Dwarka beach, Saurashtra Coast, in the month of June, 1989.

A total of twenty-one samples were collected from surface sand of Dwarka beach along the coastline from seven stations, covering a distance of about one km. At each station three samples were collected. The sampling was carried out from southern to northern end of the beach. As no difference in foraminiferal assemblages belonging to different samples was observed, all the samples are treated

as one for the purpose of the present study.

3.2.2 Laboratory method

Firstly, a 250 gram material from each sample was spilitted by a microsplitter. The material was then screened and washed through standard sieves of 30, 60 and 120 mesh and was allowed to dry in an oven at 50°C.

Ten grams of each screened sample was then treated with carbon teterachloride (CCl_4) for concentration of rare foraminiferal tests (Cushman, 1948) and entire as well as broken tests of foraminifera were picked out. The remaining material was also examined under Stereoscopic Binocular Microscope for picking the heavier foraminiferal tests which could not float in CCl_4. Picked material was finally arranged in faunal group slides for identification and study. The specimens were also examined under a Scanning Electron Microscope HITACHI-2300 model in the Department of Zoology, Aligarh Muslim University, Aligarh for detailed taxonomic study and for preparation of microphotographs of the foraminiferal species.

One gram of beach sand was also subjected to microscopic examination for observing the character and composition of the beach material.

C H A P T E R - I V

SYSTEMATIC DESCRIPTION

4.1 Classification

Various classifications of foraminifera have been proposed by different workers in the past. However, in the present study, the classification proposed by Loeblich and Tappan (1964) has been followed.

Different genera belonging to order Foraminiferida, have been arranged according to Loeblich and Tappan (1964) while different species within a genus have been placed in an alphabetical order. Synonymies, as far as possible, have been considerably reduced. However, important shifts in the generic names have been included. As far as different sides of a trochoid or partially trochoid foraminiferal test are concerned, the terminology proposed by Belford (1966) has been used, according to which the side nearest to the proloculus is termed as dorsal while the opposite side is ventral.

4.2 Repository of Type Material

All types and figured specimens have been deposited in the micropalaeontological laboratory of Department of Geology, Aligarh Muslim University, Aligarh. In the text, they have been prefixed with the word AMUGD Cat. No. MF -

4.3 Systematics

ORDER	FORAMINIFERIDA	Eichwald, 1830
Suborder	TEXTULARIINA	De'lage and Herouard, 1896
Superfamily	LITUOLACEA	de Blainville, 1825
4.3.1 Family	TEXTULARIIDAE	Ehrenberg, 1838
Subfamily	TEXTULARIINAE	Ehrenberg, 1838
Genus	TEXTULARIA	Defrance, 1824

Textularia agglutinans d'Orbigny

Plate 2, fig.1

Textularia agglutinans d'ORBIGNY, 1839, pp. 32-34, pl. 1, figs. 17, 18. - BRADY, 1884, pl. 43, figs. 1-3. - GANAPATI and SATYAVATI, 1958, p. 106, pl. 1, fig. 14 - SETHULAKSHMI AMMA, 1958, p. 39, pl. 2, fig. 57 - ANTONY, 1968, pp. 20, 21, pl. 1 fig. 9 - RAO, 1971 b, p. 156, fig. 9 - ALMEIDA and SETTY, 1972, p.96, pl.1, figs. 6-8 - ZOBEL, 1973, pl.1. fig. 28 - RAO and RAO, 1974, pl. 1, fig. 7.

Description : Test of medium size, elongate, nearly twice as long as broad, tapering towards the initial end ; periphery slightly lobulate; chambers numerous, distinct, increasing gradually as added, chambers near the apertural end slightly inflated; sutures distinct, slightly depressed; aperture slit like, at the inner margin of last chamber; wall arenaceous ; surface rough in appearance.

Dimensions (in mm) : Length 0.66, breadth 0.34, and thickness 0.30.

Remarks : Textularia agglutinans d'Orbigny, 1839 is a cosmopolitan species thriving in shallow waters. Norton (1930) reported it from beach to 110 m depth with temperature range from 20° to 27°C from Florida and West Indian region. From East Coast of India Ganapati and Satyavati (1958) recorded it from Vishakhapatnam at 44 to 190 m depth and 13.3° to 24.4°C temperature range. Almeida and Setty (1972) reported this species from Vishakhapatnam at 55 to 74 m depth range while Rao and Rao (1974) described it from Suddagudda estuary with organic carbon content ranging from 0.40 to 2.42%. From West Coast Sethulakshmi Amma (1958) reported this species from Travancore Coast and Antony (1968) described it from Kerala coast from 22 to 83 m depth.

Occurrence : Rare

Repository of type material : AMUGD Cat. No. MF - 462

Textularia foliacea Heron-Allen and Earland

Plate 2, fig.3

Textularia foliacea HERON-ALLEN and EARLAND, 1915, p. 628, pl. 47, figs. 17-20 - CUSHMAN, 1932, p. 8, pl. 1, figs. 6-10 - BHATIA, 1956, p. 17, pl. 1, fig. 1 - SETHULAKSHMI AMMA, 1958, p. 41, pl. 2, fig. 61 - ANTONY, 1968, p. 22, pl. 1, fig. 12 - BHALLA and LAL, 1985, p. 430 - BHALLA and GAUR, 1987, p. 123, pl. 1, fig. 1 - SHAREEF and VENKATACHALAPATHY, 1988, p. 433, pl. 1, fig. 2.

Description : Test of large size, elongate, nearly twice longer than broad, compressed, tapering; periphery lobulate; chambers numerous, gradually increasing in size as added, later chambers inflated; sutures rather indistinct, deeply excavated; aperture an arched slit at the inner edge of last chamber; wall arenaceous; surface fairly rough, composed of coarse and rounded sand grains.

Dimensions (in mm) : Length 0.72 to 0.78, breadth 0.36 to 0.42 and thickness 0.24 to 0.30.

Remarks : In the present material Textularia foliacea Heron-Allen and Earland, 1915, occurs frequently. Bhatia (1956) reported it as rare species from Bhogat beach, Saurashtra coast. Sethulakshmi Amma (1958) described it from Travancore coast. Bhalla and Lal (1985) described this species from Okha beach sand, Saurashtra coast. Bhalla and Gaur (1987)

reported this species from Colva beach sand and Shareef and Venkatachalapathy (1988) described Textularia foliacea from Devgad and Bhatkal islands, West Coast of India.

Occurrence : Frequent

Repository of type material : AMUGD Cat. No. MF - 463

Textularia aff. T. kerimbaensis Said

Plate 2 , fig.2

aff. Textularia kerimbaensis SAID, 1949, p.26, pl.1, fig.8 - BAHAFZALLAH, 1975, pl.2, figs. 5, 6.

aff. Textularia conica var. corrugata HERON-ALLEN and EARLAND, 1915, p. 629, pl. 47, figs. 24-27.

aff. Textularia corrugata Heron-Allen and Earland - CUSHMAN, 1932, p. 12, pl. 3, figs. 2-4, - LALICKER and CULLOCH, 1940, p. 126, pl. 14, fig. 9.

Description : Test of medium size, largely constructed of minutely rounded particles, cone-shaped, only slightly longer than broad; periphery lobulate; chambers many, early formed chambers small, later increasing rapidly as added, arranged biserially; sutures distinct, slightly depressed; aperture in the form of slit at the inner margin of last chamber; wall arenaceous; surface slightly rough.

Dimensions (in mm) : Length 0.48, breadth 0.45 and thickness 0.27.

Remarks : A single specimen which has affinity with Textularia kerimbaensis Said, 1949, was found in the present material. This species, first described by Said (1949) from Kerimba Archipelago, is a predominantly Pacific form and is found at many shallow and mid depth stations in Red Sea.

Bahafzallah (1975) described this species from Red Sea. However, our specimen differs from the one described by Bahafzallah (1975) in the inflation of the final chamber.

Occurrence : Rare

Repository of type material : AMUGD Cat. No. MF - 464

Textularia cf. T. punjabensis Haque

Plate 2, fig. 4

cf. Textularia punjabensis HAQUE, 1956, p. 31, pl. 9, figs. 12 a, b

Description : Test of medium size, elongate, nearly one and half times longer than broad, maximum width at apertural end; peripheral margin entire, very slightly depressed in later part; chambers distinct, nearly uniform in shape, broader than high, increasing gradually towards apertural end, final chamber somewhat inflated; sutures distinct, nearly flush in early portion, median suture zig-zag; aperture an arched opening at the inner margin of last chamber; wall arenaceous; surface more or less smoothly finished.

Dimensions (in mm) : Length 0.63, breadth 0.48 and thickness 0.36.

Remarks : A single specimen which has been compared with Textularia punjabensis Haque, 1956, was found in the present material. However, our specimen differs from the one described by Haque (1956) as in the present form chambers increase gradually and only final chamber is inflated. Moreover, sutures in our specimen are flush in the early portion and very slightly depressed in later part whereas they are distinctly depressed in the specimen described by Haque (1956).

Occurrence : Rare

Repository of type material : AMUGD. Cat. No. MF - 465

Textularia rugosa Costa

Plate 2, fig.5

Textularia rugosa Costa, 1856, p. 365, pl. 15, fig.7a - BRADY, 1884,p.363, pl.42, figs. 23, 24 - HERON-ALLEN and EARLAND, 1915, p. 625, pl.47, figs. 7-9.

Description : Test of medium size, elongate tapering,nearly one and half times longer than broad, somewhat triangular in shape; periphery slightly lobulate; chambers numerous, distinct, gradually increasing in size as added, last two chambers somewhat inflated; sutures indistinct, slightly excavated; aperture oval in shape,at the inner margin of last chamber; wall arenaceous; surface fairly rough.

Dimensions (in mm) : Length 0.69, breadth 0.39 and thickness 0.27.

Remarks : A single specimen of Textularia rugosa was found in the present material which resembles with the one described by Costa (1865). This is the first record of this species from Indian waters.

Occurrence : Rare

Repository of type material : AMUGD Cat. No. MF - 466

Suborder	MILIOLINA	D'elage and Herouard, 1896
Superfamily	MILIOLACEA	Ehrenberg, 1839
4.3.2. Family	NUBECULARIIDAE	Jones, 1875
Subfamily	SPIROLOCULININAE	Wiesner, 1920
Genus	SPIROLOCULINA	d'Orbigny, 1826

Spiroloculina indica Cushman and Todd

Plate 2, fig.6

Spiroloculina indica CUSHMAN and TODD, 1944, p.71, pl.9, figs. 32 a,b - BHATIA, 1956, p. 18, pl. 2, figs. 5 a,b - ROCHA and UBALDO, 1964 a, p. 412, pl. 2, fig. 2, 1964 b, p. 649, pl. 2, fig. 9 - ZOBEL 1973, p. 14, pl. 1, fig. 17 - BHATIA and KUMAR, 1976, p. 243, tab. 2, - BHALLA and LAL , 1985, p. 430.

Description : Test of medium size, about one and half times longer than broad, fusiform in outline with central portion slightly depressed; periphery rectangular in apertural view, rounded in side view, edges strongly angled; chambers distinct, half a coil in length, enlarging rapidly as added; sutures distinct, depressed, curved; aperture rounded, placed on a distinct neck having lip, with bifid tooth on inner margin and simple tooth on outer margin of aperture; wall porcellaneous, imperforate; surface smooth.

Dimensions (in mm) : Length 0.66, breadth 0.42 and thickness 0.15

Remarks : A single specimen of spiroloculina indica Cushman and Todd, 1944, has been found in the present material. Cushman and Todd (1944) described S. indica for the first time from Recent shore sand of Karachi, Pakistan. From Indian waters different workers have reported it from both East and West Coasts of India. From West Coast of India Bhatia (1956) reported this species from Juhu and Bhogat beaches. Rocha and Ubaldo (1964 b) described it from Gogola and Baga beaches, Bhatia and Kumar (1976) reported it from around Anjidiv island at 5 to 13 depth, 28.7° to 30.1°C temperature, 8.7 to 10.8 pH, 33.77 to 35.1‰ salinity, 3.85 to 4.92ml/l dissolved oxygen and 1.24 to 41.96% $CaCO_3$ range. From East Coast Rao et al. (1973) described S. indica from shelf sediments of Vishakhapatnam at 60 m depth, 17 to 34‰ salinity, 22° to 30°C temperature, 8 to 11.5% $CaCO_3$ range and from silty clay substrate.

Occurrence : Rare

Repository of type material : AMUGD Cat. No. MF - 467

4.3.3 Family MILIOLIDAE Ehrenberg, 1839

Subfamily QUINQUELOCULININAE Cushman, 1917

Genus QUINQUELOCULINA d'Orbigny, 1826

Quinqueloculina aff. Q. oculus d'Orbigny

Plate 2, fig.8

aff. Quinqueloculina oculus d'ORBIGNY, 1878, p. 21, fig.14.

Description : Test of large size, quinqueloculine in plan, one and half times longer than broad, ovate in side view, subtriangular in end view; periphery rounded; chambers distinct, successive chambers enlarging rapidly as added, upper portion of final chamber ornamented with numerous costae; sutures distinct, depressed; aperture rounded with bifid tooth, placed on a small neck; wall porcellaneous, imperforate; surface smooth.

Dimensions (in mm) : Length 0.75, breadth 0.48 and thickness 0.33.

Remarks : A single specimen having affinity with Quinqueloculina oculus d'Orbigny, 1878, was found in the present material. However, our specimen differs from the original in possessing numerous costae in the upper portion of the final chamber.

Occurrence : Rare

Repository of type material : AMUGD Cat. No. MF - 468.

Quinqueloculina pseudoreticulata Parr

Plate 2, fig.9

Quinqueloculina pseudoreticulata PARR, 1941, p. 177, pl. 9, figs. 2, 3 - ROCHA and UBALDO, 1964 a, p. 412, pl. 1, figs. 4 a, b, 1964 b, p.649, pl. 2, figs. 3,4. - RASHEED, 1967-68, p.29, fig.15 - BHALLA and NIGAM, 1979, p.239 - SHAREEF and VENKATACHALAPATHY, 1988, p.434, pl. 2, figs.3 a, b.

Description : Test of medium to large size, subelliptical in outline, triangular in apertural view, longer than broad; periphery subrounded, rounded in apertural view; chambers distinct, three visible on one side, four on the other side, half a coil in length, quinqueloculine in arrangement, increasing gradually as added, second chamber rather inflated in four-chambered view; sutures distinct, simple, depressed; aperture terminal, subrounded, with simple tooth; wall porcellaneous; surface ornamented with numerous rounded to subrounded pits, giving an impression of reticulate pattern.

Dimensions (in mm) : Length 0.48 to 0.78, breadth 0.41 to 0.55 and thickness 0.33 to 0.42.

Remarks : Parr (1941) described Quinqueloculina pseudo-reticulata for the first time from South Australia. This species is characterised by its rounded to subrounded pits resembling a reticulate ornamentation. Quinqueloculina pseudoreticulata seems to be a warm shallow water species

because Brady (1884) reported this species at a depth of 28 fathoms near New Guinea, Pacific Ocean. Rasheed (1967, 68) also reported it from New Guinea, in Coral Sea, south of Papua. From Indian waters Bhalla and Nigam (1979) reported this species from Calangute beach sands, Goa, and Shareef and Venkatachalapathy (1988) described this species from Devgad and Bhatkal islands, West Coast India. Rocha and Ubaldo (1964 b) reported this species from Jampore and Baga beaches from West Coast of India.

Occurrence : Abundant

Repository of type material : AMUGD Cat. No. MF - 469

Quinqueloculina seminulum (Linnaeus)

Plate 2, fig.7

Serpula seminulum LINNAEUS, 1758, p.786

Quinqueloculina seminulum (Linnaeus) d'ORBIGNY, 1826, p. 303, - BHATIA, 1956, p. 17, pl. 2, fig. 9 - BHATIA and BHALLA, 1959, p. 79, pl. 1, figs. 1 a, b - ANTONY, 1968, p. 30, pl. 1, fig. 23 - BHALLA, 1968, pp. 380, 381, pl. 1, figs. 1 a, b, 1970, pp. 156, 157, pl. 20, figs. 1 a,b - RAO, 1970 a, p. 589, figs. 12 a, b - RAO and RAO, 1974, pl. 1, fig. 11 - BHATIA and KUMAR, 1976, p. 242 - BHALLA and NIGAM, 1979, pp. 239, 240 - SRIVASTAVA et al., 1984, p. 36 - BHALLA and LAL, 1985, p. 430, - BHALLA and GAUR, 1987, p. 123, pl. 1, fig. 6, - SHAREEF and VENKATACHALAPATHY, 1988, p. 436, pl. 1, fig. 9.

Description : Test of medium size, quinqueloculine in plan, about one and half times longer than broad, oval in side view; periphery rounded; chambers distinct, tubular, increasing rather rapidly as added, half a coil in length, four visible on one side and three on the other side; sutures distinct, depressed; aperture terminal, rounded, with bifid tooth; wall porcellaneous, imperforate; surface smooth.

Dimensions (in mm) : Length 0.45 to 0.66, breadth 0.39 to 57 and thickness 0.26 to 0.45

Remarks : Quinqueloculina seminulum (Linnaeus) is a cosmopolitan species which exhibits a wide range of tolerance to salinity and temperature. Kane (1967) recorded this species from estuarine to truly marine conditions and it has been widely reported from near shore water in association with other thick walled foraminifers.

From Indian region it has been reported from various beaches of both the East and West Coasts of India by different workers.

Occurrence : Common

Repository of type material : AMUGD Cat. No. MF - 470

Quinqueloculina sulcata d'Orbigny

Plate 2, fig.10

Quinqueloculina sulcata d'Orbigny, 1826, p. 301, 1900, p. 304, - CUSHMAN, 1932, p. 28, pl. 7, figs. 5-8 - RASHEED, 1967-68, pp. 24, 25, pl. 3, figs. 2 a-c - RAGOTHAMAN and MANIVANNAN, 1985, p. 130, pl. 1, fig. 22.

Description : Test of medium size, quinqueloculine in plan, nearly one and half times longer than broad, oval in side view; periphery rounded; chambers distinct, three chambers visible on one side and four on other side, second chamber on the four-chambered side much inflated, increasing gradually as added; sutures distinct, slightly depressed; aperture terminal, circular, with bifid tooth; wall porcellaneous, imperforate; surface ornamented with a few distinct longitudinal ridges, running along the entire length of test.

Dimensions (in mm) : Length 0.51, breadth 0.30 and thickness 0.21

Remarks : A single specimen of Quinqueloculina sulcata d'Orbigny, 1826, has been found in the present material which is characterised by a few distinct longitudinal ridges running along the entire length of test. This species is also reported by Ragothaman and Manivannan (1985) from Mandapam Coast, Ramanathapuram district, Tamil Nadu. However, the present specimen is smaller in size in

comparison to the one described by Ragothaman and Manivannan (1985).

Occurrence : Rare

Repository of type material : AMUGD Cat. No. MF - 471

Quinqueloculina undulose-costata Terquem

Plate-3, fig. 7

Quinqueloculina undulose-costata TERQUEM, 1882, p. 185, pl. 20, figs. 18, 19 - BHATIA 1956, p. 17, pl. 2, fig. 8 - BHATIA and KUMAR, 1976, p. 242, tab. 2- SHAREEF and VENKATACHALAPATHY, 1988, p. 434, pl. 2,figs. 4 a, b.

Description : Test of medium size, slightly longer than broad, rounded in side view; periphery subrounded; chambers quinqueloculine in arrangement, enlarging rapidly as added, uniform in thickness, embracing earlier chambers moderately, first chamber indistinct in four-chambered view, last chamber slightly protruding at base; sutures rather indistinct, simple, depressed; aperture terminal, semicircular, without a neck; wall porcellaneous, imperforate; surface ornamented with thick costae, oblique to periphery.

Dimensions (in mm) : Length 0.48 to 0.54, breadth 0.36 to 0.45 and thickness 0.33 to 0.36

Remarks: Quinqueloculina undulose-costata Terquem, 1882, is characterised by its thick costae which are oblique to the periphery. Bhatia (1956) reported rare occurrence of this species from Bhogat beach sand, Saurashtra coast. Bhatia and Kumar (1976) described Q. undulose-costata from around Anjidiv island, West Coast of India at 5 m to 14.5 m depth range and 33.49 to 35.01‰, salinity range. Shareef and

Venkatachalapathy (1988) described this species from Bhatkal and Devgad islands, West Coast of India. Our specimens resemble closely with the one described by Shareef and Venkatachalapathy (1988).

Occurrence : Frequent

Repository of type material : AMUGD Cat. No. MF - 472

Quinqueloculina vulgaris d'Orbigny

Plate 3, fig. 1

Quinqueloculina vulgaris d'ORBIGNY, 1826, p. 302 - CUSHMAN, 1929, p. 25 - SETHULAKSHMI AMMA, 1958, pp. 4,5, pl. 1, fig. 5 - GANAPATY and SATYAVATI, 1958, pl. 1, figs. 24-26 - ROCHA and UBALDO, 1964 a, p. 647, pl. 1, fig. 6 a, b - ANTONY, 1968, p. 29, pl. 1, fig. 22 -BHALLA, 1970, pp. 156-163, pl. 20, figs. 3 a, b - RAO, 1971 a, p. 157, 1971 b, p. 589, fig. 11 a,b - BHALLA and NIGAM, 1979, p. 239 - SHAREEF and VENKATACHALAPATHY, 1988, p. 434, pl.1, figs. 10 a-c.

Description : Test of medium size, stout, quinqueloculine in plan, only slightly longer than broad, rounded in side view, nearly triangular in end view ; periphery rounded ; chambers distinct, enlarging rapidly as added, initial chamber on the four-chambered side much smaller than the second one; sutures simple, distinct, fairly depressed; aperture terminal, rounded, with bifid tooth; wall porcellaneous, imperforate; surface smooth.

Dimensions (in mm) : Length 0.42, breadth 0.30 and thickness 0.24

Remarks : Quinqueloculina vulgaris d'Orbigny, 1826, is a cosmopolitan species and has been recorded from both cold and warm water at various depths.

From West Cost of India, Sethulakshmi Amma (1958)

reported it from Travancore Coast. Bhalla and Nigam (1979) recorded it from Calangute beach sand and Shareef and Venkatachalapathy reported this species from Devgad and Bhatkal islands, West Coast of India. From East Coast, Ganapati and Satyavati (1958) described this species from off the Coast of Madras at a depth of 12 to 97 fathoms and 71° to 80° F temperature ranges. Bhalla (1970) reported this species from Marina beach sand, Madras. A single specimen of this species has been found in the present material which resemble closely to the one described by Shareef and Venkatachalapathy (1988).

Occurrence : Rare

Repository of type material : AMUGD Cat. No. MF - 473

Quinqueloculina sp.

Plate 3, fig. 3

Description : Test of medium size, quinqueloculine in plan, more than one and half times as long as broad, oval in side view, nearly elliptical in end view; periphery rounded; chambers distinct, three on one side and four on other side, increasing rapidly in size as added, middle chamber in the three-chambered view rather small; top of the final chamber ornamented with a few indistinct ridges; sutures distinct, depressed; aperture rounded, with simple tooth, placed on a small neck; wall porcellaneous; surface more or less smooth.

Dimensions (in mm) : Length 0.69, breadth 0.45 and thickness 0.27

Remarks : A single specimen of this undeterminable species was found in the Dwarka beach material which has no resemblance with any known species of Quinqueloculina. However, more specimens are required to identify it at species level.

Occurrence : Rare.

Repository of type material : AMUGD Cat. No. MF - 474

Triloculina aff. T. inornata d'Orbigny

Plate 3, fig. 4

aff. Triloculina inornata d'Orbigny, 1846, pl. 17, figs. 16-18

aff. Triloculina inornata var. longidentata BRADY, 1953, pl. 21, figs. 2 a-c.

Description : Test of medium size, elongate, triloculine in plan, oval in side view, nearly triangular in end view; periphery rounded; chambers distinct, increasing rather rapidly as added, first chamber fairly inflated in tree-chambered view, second chamber strongly curved, fairly large; sutures distinct, depressed; aperture circular with birid tooth; wall porcellaneous, imperforate; surface smooth.

Dimensions (in mm) : Length 0.54, breadth 0.42 and thickness 0.33.

Remarks : A single specimen showing affinity with Triloculina inornata d'Orbigny was found in the present material. However, our specimen differs in having a slightly longer apertural neck.

Occurrence : Rare

Repository of type material : AMUGD Cat. No. MF - 475

Triloculina terquemiana (Brady)

Plate 3, fig.5

Miliolina terquemiana BRADY, 1884, p. 106, pl. 114, fig. 1 a, b

Triloculina terquemiana CUSHMAN, 1916, p. 72, pl. 2, fig. 2 - BHATIA, 1956, p. 19, pl. 2, fig. 3 - SETHULAKSHMI AMMA, 1958, p. 9, pl. 1, figs. 15 a, b - ROCHA and UBALDO, 1964a, p. 413, pl. 2, fig. 5 - BHALLA, 1968, p. 381, pl. 1, figs. 5 a, b - RAO, 1971 a, p. 157, fig. 15 - BHALLA and NIGAM, 1979, pp. 239, 240 - BHALLA and LAL, 1985, p. 430 - BHALLA and GAUR, 1987, p. 123, pl. 1, fig. 8

Description : Test of medium size, triloculine in plan, oval in side view, triangular in end view; periphery bluntly angular; chambers distinct, added at planes 120^{o} apart, half coil in length; sutures distinct, simple, gently depressed; aperture terminal, oval in shape, with bifid tooth; wall porcellaneous, imperforate; surface ornamented with numerous prominent costae, closely spaced, running along the entire length of test.

Dimensions (in mm) : Length 0.42 to 0.63, breadth 0.33 to 0.48 and thickness 0.33 to 0.42.

Remarks : Brady (1884) first described Triloculina terquemiana from shore sand of Madagascar in the Indian Ocean. From West Coast of India, Bhatia (1956) reported this

species from shore sand of Bhogat, Saurashtra coast, followed by Sethulakshmi Amma (1958) from Travancore Coast, Rocha and Ubaldo (1964a) from Diu beach sand, Bhalla and Nigam (1979) from Calangute beach sand, Goa, Bhalla and Lal (1985) from Okha beach sand, Saurashtra coast, and Bhalla and Gaur (1987) from Colva beach sand, Goa.

From East Coast of India, Bhalla (1968) recorded this species from Vishakhapatnam beach sand.

Occurrence : Frequent

Repository of type material : AMUGD Cat. No. MF - 476

Triloculina trigonula (Lamarck)

Plate 3, fig.6

Miliolites trigonula LAMARCK, 1804, p. 351, pl. 17, fig. 4.

Miliolina trigonula Williamson - BRADY, 1884, p. 164, pl. 3 figs. 14-16.

Triloculina trigonula (Lamarck) - d'ORBIGNY, 1826, p. 229, pl. 16, figs. 5-9 - BHATIA and BHALLA, 1959, P. 79, Pl. 1, figs. 5 a, b - ROCHA and UBALDO, 1964 a, p. 411, pl. 5, rigs. 5 a, b - BHALLA, 1968, p. 382, pl. 1, figs. 2 a, b - BHALLA, 1970, p. 157, pl. 20, figs. 4 a, b - SRIVASTAVA et al. 1984, p.36, pl. 1, fig. 3 - BHALLA and LAL 1985, p. 430. - SHAREEF and VENKATACHALAPATHY, 1988, p. 434, pl. 2, fig.5.

Description : Test of medium size, triloculine in plan, oval in side new, triangular in end view; periphery smooth, rounded, bluntly angled in end view; chambers distinct, added at 120°, half coil in length; sutures distinct, slightly depressed; aperture rounded, with bifid tooth; wall porcellaneous, imperforate; surface smooth.

Dimensions (in mm) : Length 0.36 to 0.60, breadth 0.33 to 0.51 and thickness 0.34 to 0.36

Remarks : The first report of Triloculina trigonula was by Lamarck (1804) from sediments of France and later it has been reported from different parts of the world. Albani (1965)

reported it from Durban Bay, South Africa. T. trigonula has been recorded from the Recent sediments of both East and West Coasts of India.

From West Coast of India T. trigonula has been described by Rocha and Ubaldo (1964a) from Diu, Gogola and Simbor beaches, Srivastava et al. (1984) described it from near Veraval, Saurashtra Coast, Bhalla and Lal (1955) reported this species from Okha beach sand and Shareef and Venkatachalapathy (1988) reported it from Bhatkal and Devgad island beach sand.

From East Coast Bhatia and Bhalla (1959) reported it from Puri beach sand, and Bhalla (1968, 70) from Vishakhapatnam and Marina beach, Madras respectively. Our specimens resemble closely with the one described by Bhalla (1970) from Marina beach sand, Madras.

Occurrence : Abundant

Repository of type material : AMUGD Cat. No. MF - 477

Triloculina aff. T. unidentata d'Orbigny

Plate 3, fig.2

aff. Triloculina unidentata d'ORBIGNY, 1900, p. 361, fig. 6.

Description : Test of medium size, triloculine in plan, oval in side view, triangular in end view; periphery smooth, rounded; chambers distinct, increasing gradually in size as added, in three-chambered view first chamber slightly inflated, second and final chambers strongly curved, in two-chambered view first chamber somewhat triangular in shape, final chamber abruptly curved towards apertural and basal ends; sutures distinct; aperture large, rounded, with bifid tooth; wall porcellaneous, imperforate; surface smooth.

Dimensions (in mm) : Length 0.63, breadth 0.51 and thickness 0.36.

Remarks : A single specimen which has affinity with Triloculina unidentata d'Orbigny, 1900, was found in the present material. Our specimen resembles with the one described by d'Orbigny (1900) except that it lacks an apertural neck.

Occurrence : Rare

Repository of type material : AMUGD Cat. No. MF - 478

Suborder	ROTALIINA	D'elage and Herouard, 1896
Superfamily	DISCORBACEA	Ehrenberg, 1838
4.3.4. Family	DISCORBIDAE	Ehrenberg, 1838
Subfamily	DISCORBINAE	Ehrenberg, 1838
Genus	DISCORBIS	Lamarck, 18104

Discorbis sp.

Plate 3, fig.8

Description : Test of medium size, rounded, trochospiral, plano-convex; periphery rounded, keeled; dorsal side evolute, chambers numerous, distinct, increasing gradually as added, dorsal sutures distinct, slightly raised, curved, bent backward towards periphery; ventral side involute, only last whorl visible, chambers numerous, ventral sutures distinct, more or less straight, excavated; aperture interiomarginal, a slit at the base of last chamber; wall calcareous, coarsely perforate; surface smooth.

Dimensions (in mm) : Major diameter 0.45 to 0.51, minor diameter 0.39 to 0.43 and thickness 0.25 to 0.27

Remarks : Only two specimens of this undeterminable species were found in the present material which have no resemblance to any known species of the genus Discorbis. However, more specimens are needed to assign a trivial name.

Occurrence : Rare

Repository of type material : AMUGD Cat. No. MF - 479

Superfamily	ROTALIACEA	Ehrenberg, 1839
4.3.5. Family	ROTALIIDAE	Ehrenberg, 1839
Subfamily	ROTALIINAE	Ehrenberg, 1839
Genus	CAVAROTALIA	Muller-Merz, 1980

Cavarotalia annectens (Parker and Jones)

Plate 4, fig. 7

Rotalia beccarii (Linnaeus) var. annectens PARKER and JONES, 1865, p. 387, pl. 19, figs. 11 a-c

Rotalia annectens (Parker and Jones) - MILLET, 1904, p. 505, pl. 10, figs. 6 a-c.

Streblus annectens (Parker and Jones) - ISHIZAKI, 1940, p. 58, pl. 3, figs. 12, 13 - BHATIA, 1956, p. 22, pl. 3, figs. 1, 2 - BHATIA and BHALLA, 1959, p. 79, pl. 2, figs. 1 a-c - ROCHA and UBLADO, 1964 a , pp. 407-420, pl. 4, figs. 3 a-c, 1964 b, p. 647, pl. 2, figs. 13, 14.

Ammonia annectens (Parker and Jones) - HUANG - 1964, pp. 50-52, pl. 2, fig. 3; pl. 3, figs. 1, 2, text-fig. 3 - BHALLA, 1970, p. 158, pl. 20, figs. 8 a-c - BHATIA and KUMAR, 1976, p. 247, tab. 1 - BHALLA and NIGAM, 1979, O. 239 - BHALLA and RAGHAV, 1980, p. 289 - SRIVASTAVA et al., 1984, p. 41, pl. 1, fig. 4

Cavarotalia annectens (Parker and Jones) - MULLER-MERZ, 1980, p. 28, text-fig. 10, 26, 27, pl. 13, fig. 3 - BHALLA and

GAUR, 1987, p. 124, pl. 2, figs. 6 a, b.

Description : Test of medium to large size, nearly rounded, trochospiral, biconvex; periphery lobulate, keeled; dorsal side evolute, chambers of dorsal side distinct, numerous, enlarging gradually as added, dorsal sutures distinct, limbate, slightly raised, curved; ventral side involute, with eleven chambers, sutures distinct, thick, excavated, almost straight, narrowing towards periphery; umbilical area covered with shell material; aperture distinct, interiomarginal, on ventral side in the form of proto and deutero foramen; wall calcareous, finely perforate; surface smooth.

Dimensions (in mm) : Major diameter 0.54 to 0.78, minor diameter 0.43 to 0.66 and thickness 0.30 to 0.38.

Remarks : Cavarotalia annectens (Parker and Jones) occurs abundantly in Dwarka beach material. It is considered as characteristic Indo-Pacific species. Cavarotalia annectens shows as wide range of variation in shape and size of test and number of chambers. It has been recorded from West Coast of India by Bhatia (1956), Rocha and Ubaldo (1964a, b), Bhalla and Nigam (1979), Bhalla and Raghav (1980), and Srivastava et al. (1984). Bhatia and Bhalla (1959) and Bhalla (1970) also recorded it from East Coast of India. Bhatia and Kumar (1976) reported it from Anjidiv island at 5-14 m depth, 28° to 31.1°C temperature, and 33.49 to 35.01‰ salinity

range.

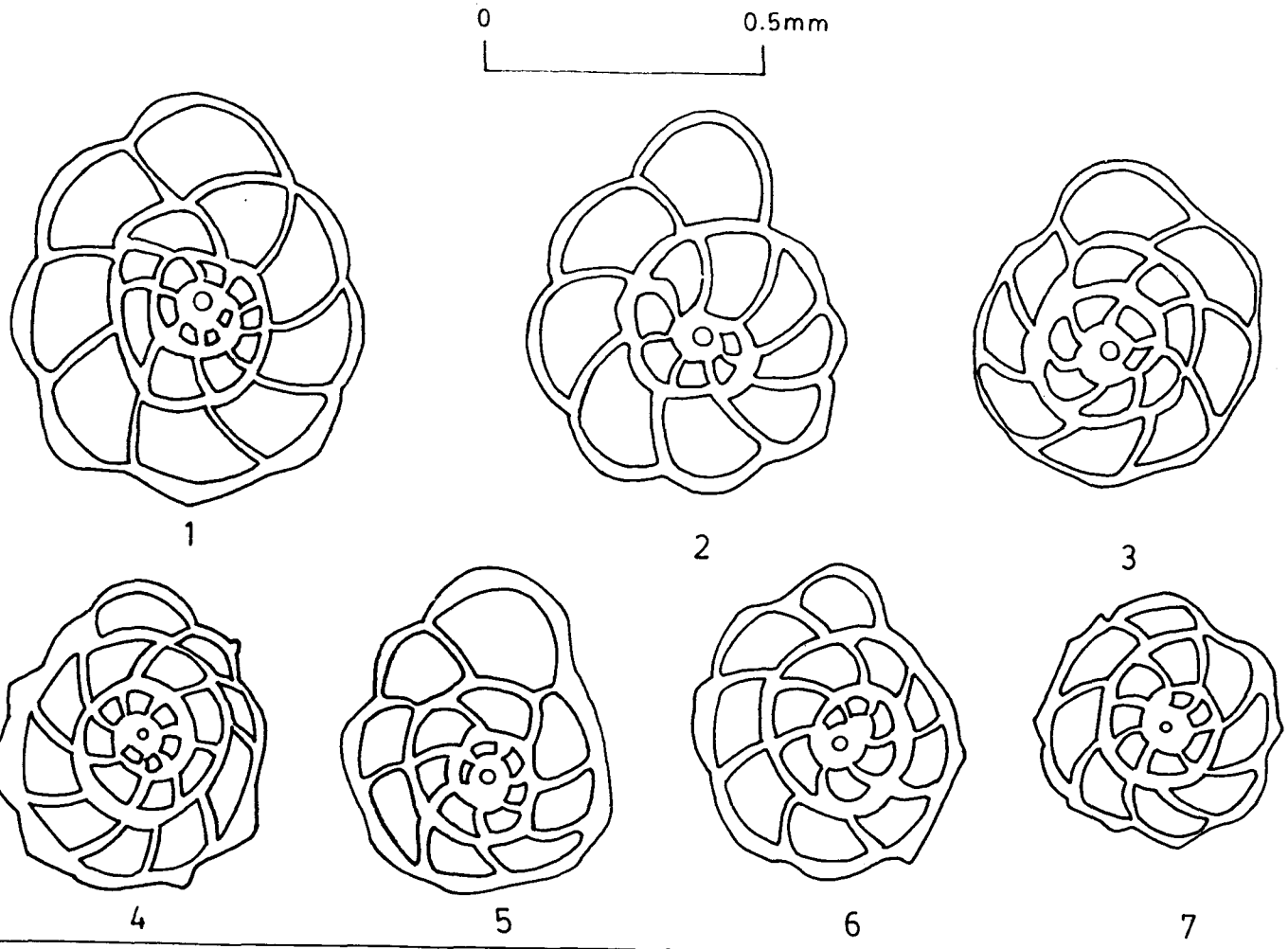
Occurrence : Abundant

Repository of type material : AMUGD Cat. No. MF - 480

Text - fig. 2

Text-fig. 2

Variation in Pararotalia boltovskoyi Jain and Bhatia



Genus PARAROTALIA Le Calvez, 1949

Pararotalia boltovskoyi Jain and Bhatia

Plate 4, fig. 5

Pararotalia boltovskoyi Jain and Bhatia, 1978, p. 165, pl. 2, figs. H-I. - BHALLA and LAL, 1985, p. 430.

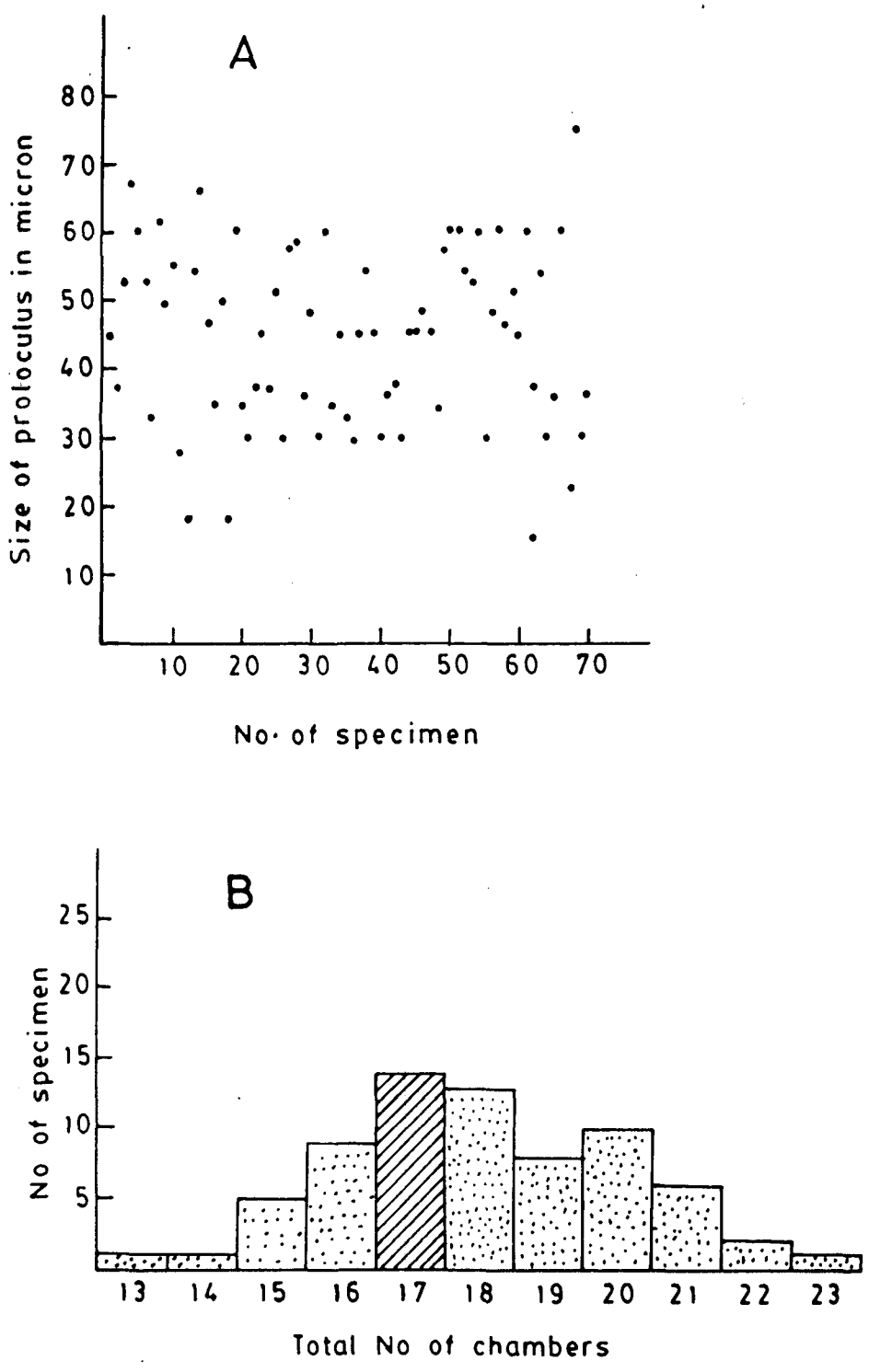
Description : Test of medium size, nearly rounded to fairly oval in shape, trochospiral, biconvex ; periphery subangular, with a broad granular keel, having blunt rounded spines except in last few chambers; dorsal side evolute with thirteen to twenty-one chambers, about two and half whorls visible on spiral side, dorsal sutures limbate, slightly depressed; ventral sutures thick, slightly curved, deeply excavated ; umbilicus deeply excavated, filled with irregular plug, umbilical plate of earlier chambers covered by umbilical shoulder; aperture interiomarginal, a slit like opening; wall calcareous, finely perforate; surface smooth.

Variation : Variation in shape, size, number of chambers and periphery of the test has been observed in Pararotalia boltovskoyi Jain and Bhatia, 1978. Seven representative specimens from the total population have been selected for variation study.

Shape of the test vary from being nearly rounded (Text-fig.2, fig.7) to fairly ovate (Text-fig.2, fig.5).

Text- fig. 3

Text-fig. 3



Scatter diagram and histogram showing relationship between various parameters of test of Pararotalia boltovskoyi Jain & Bhatia

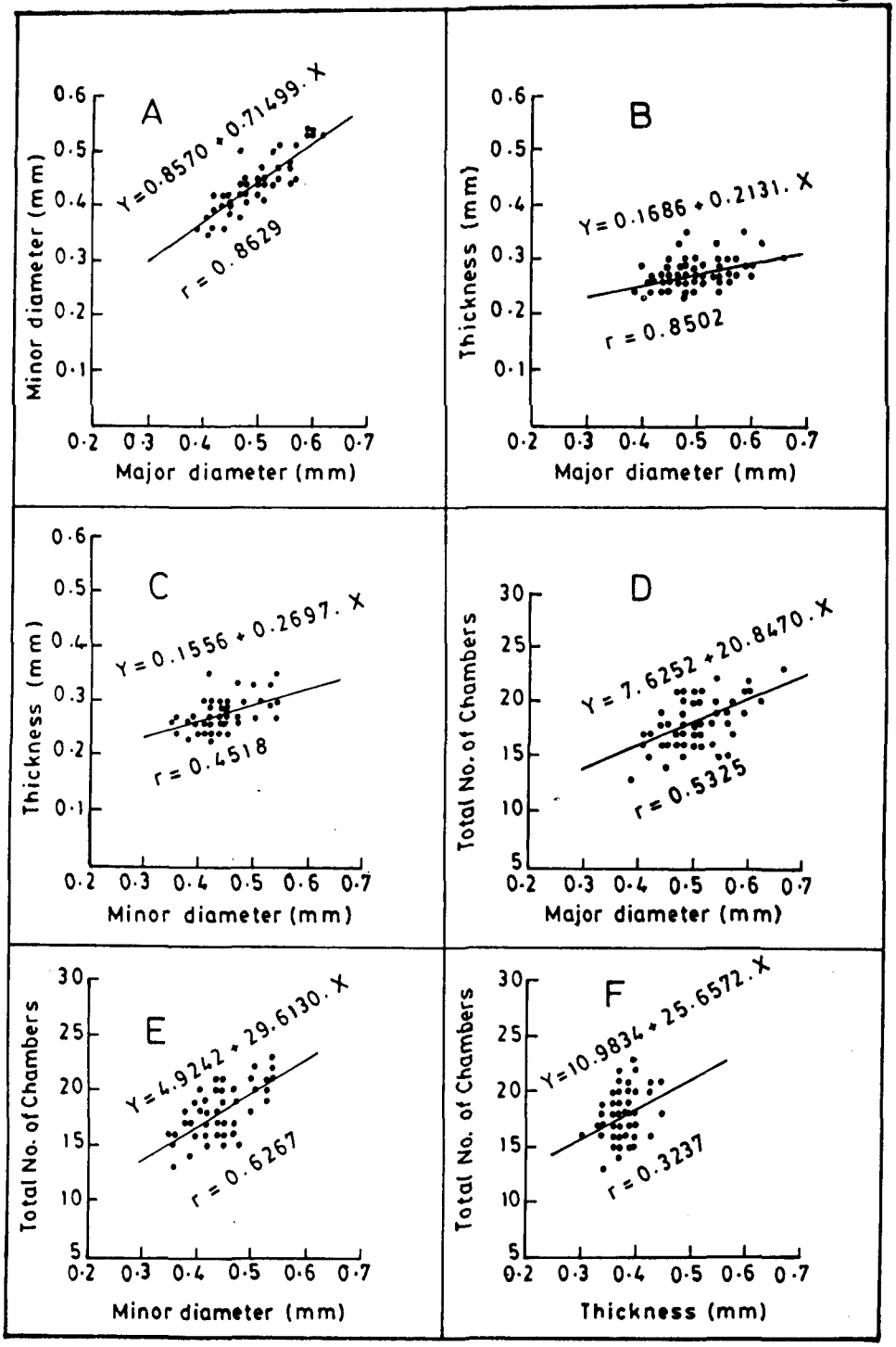
Periphery of the test shows a variation in lobulation as well as in the width of keel. Lobulation vary from slightly lobulate (Text-fig. 2, fig. 3) to highly lobulate periphery (Text-fig.2, fig.2). The peripheral keel shows variation from being relatively thin (Text-fig.2, fig.3) to fairly broad (Text-fig.2, figs.1,4). While in some specimens periphery is distinctly spinate (Text-fig.2, fig.4), in others the spines are not clearly distinguishable (Text-fig.2, fig.3,5). Shape of the last chamber also vary from being broader than high (Text fig.2, fig.3) to slightly higher than broad (Text-fig.2, fig.2). Variation in total number of chambers has also been observed as it vary from thirteen to twenty-three (Text-fig. 3, fig. B).

Scatter diagram taking total number of specimens and their proloculus size has been plotted in order to separate the dimorphic generations in this species (Text-fig. 3, fig.A). However, as the clustering of plots indicates, separate dimorphic generations could not be identified in the present population of Pararotalia boltovskoyi.

In order to determine the trend of distribution of chambers in Pararotalia boltovskoyi a histogram has been plotted taking total number of specimens and total number of chambers (Text-fig 3, fig.B). The histogram depicts that the modal class consists of seventeen chambers and include

Text- fig. 4

Text-fig.4



Scatter diagrams showing relationship between various parameters of test of Pararotalia boltovskoyi Jain & Bhatia

fourteen out of seventy specimens, constituting 20% of the total population. Specimens having larger number of chambers than the modal class exceed those having smaller number of chambers, suggesting that the distribution of chambers is slightly skewed towards specimens having larger number of chambers.

A quantitative analysis of seventy specimens of Pararotalia boltovskoyi has been carried out in order to observe the possible correlation between various parameters of test, viz., major diameter, minor diameter, thickness, and total number of chambers (Appendix-I). Scatter diagrams for different parameters have been plotted and "line of best fit" in each plot has been drawn with the help of the following equation of straight line:

$$Y_c = a + bx$$

Correlation Coefficient between various parameters has also been calculated in order to have a precise idea of the degree of correlation, using the formula

$$r = \frac{n\Sigma xy - (\Sigma x)(\Sigma y)}{\sqrt{n\Sigma x^2 - (\Sigma x)^2}\ \sqrt{n\Sigma y^2 - (\Sigma y)^2}}$$

where r = Correlation Coefficient

The graph between major diameter and minor diameter (Text-fig. 4, fig. A.) shows a high degree of positive correlation (r=0.8629), i.e., with an increase in major

diameter, minor diameter increases which indicates that elongation ratio of the test remains nearly the same throughout. A high degree of positive correlation (r= 0.8502) is also visualized between major diameter and thickness (Test-fig. 4, fig. B). It shows that the thickness of test increases with an increase in the major diameter, thereby suggesting that the flatness of test remains more or less the same throughout. Scatter diagram between minor diameter and thickness (Text-fig. 4, fig.C) indicates that with an increase in minor diameter of the test, thickness also increase, the value of correlation coefficient (r) being 0.4518. A fair degree of positive correlation (r= 0.5325) is also found between major diameter and total number of chambers (Text-fig. 4, fig D) and minor diameter and total number of chambers (r= 0.6276) (Text-fig. 4, fig. E). Therefore, increase in the total number of chambers is inferred with an increase in the size of test. The graph between thickness and total number of chambers (Text-fig 4, fig. F), however, shows a lesser degree of positive correlation (r= 0.3237) indicating a possible increase in the thickness with the addition of chamber to the test.

Dimensions (in mm) : Major diameter 0.39 to 0.66, minor diameter 0.35 to 0.54 and thickness 0.23 to 0.35.

Remarks : This distinctive species of Pararotalia which occurs abundantly in the present material was erected by Jain and Bhatia (1978) from Mandvi beach, Kutch, West Coast of India. Pararotalia boltovskoyi Jain and Bhatia, 1978, is characterized by a broad granular peripheral keel with blunt rounded spines. However, the present specimens differ slightly from those described by Jain and Bhatia (1978) in having more number of chambers in the last whorl.

Occurrence : Abundant

Repository of type material : AMUGD Cat. No. MF - 481.

4.3.6 Family	ELPHIDIIDAE	Galloway, 1933
Subfamily	ELPHIDIINAE	Galloway, 1933
Genus	ELPHIDIUM	De Montfort, 1808

Elphidium craticulatum (Fichtel and Moll)

Plate 4, fig.1

Nautilus craticulatus FICHTEL and MOLL, 1798, p. 51, pl. 5, figs. h-k.

Polystomella cracticulata BRADY, 1884, p. 739, pl. 110, figs. 16, 17.

Elphidium craticulatum (Fichtel and Moll) - CUSHMAN, 1933, p.48, pl. 1, figs. 5 a, b - BHATIA, 1956, p. 20, pl. 5, fig. 10 - GANAPATI and SATYAVATI, 1958, p. 115, pl. 3, figs. 87, 88, - GANAPATI and SAROJINI, 1959, p. 312. - ROCHA and UBALDO, 1964 a, p. 416, pl. 3, fig. 7 - ANTONY, 1968, p. 61, pl. 4, fig. 3 - RAO and RAO, 1979, p. 360 - BHALLA and NIGAM, 1979, pp. 439, 440 - BHALLA and LAL, 1985, p. 430.

Description : Test of medium size, rounded, planispiral, closely coiled, involute, biconvex, biumbonate; periphery acute, angular; twenty-eight chambers in last whorl, increasing gradually as added; sutures distinct slightly depressed, gently curved, retral processes short, indistinct, visible along suture; umbilical area with a large boss of clear test material, raised, with rounded pits on surface;

aperture distinct, a row of pores, arranged at the base of apertural face; wall calcareous; surface smooth.

Dimensions (in mm) : Major diameter 0.66, minor diameter 0.66 and thickness 0.42

Remarks : A single slightly broken specimen of Elphidium craticulatum (Fichtel and Moll) has been found in the present material which is a typical Indo-Pacific species. Norton (1930) reported it as commonly occurring species from Murray Island, Australia, at 3 to 5 m depth and 23° to 28.5°C temperature range. Uchio (1962) recorded it from different beaches along the coast of Wakayama, Ken, Japan. From West Coast of India E. craticulatum has been reported by Bhatia (1956) from Bhogat, Rocha and Ubaldo (1964 a) from Diu and Gogola beaches, Antony (1968) from Kerala coast at 23 to 183 m depth range and Nigam et al. (1979) from shelf region off Ratnagiri at 15 to 50 m depth range. From East Coast Ganapati and Satyavati (1958) reported it from Vishakhapatnam coast at 70 to 73 m depth and 20.65° to 24.99°C temperature, range. Rao et al. (1979) recorded it at 55 to 105 m and 165 to 190 m depth range from shelf region off Vishakhapatnam.

Occurrence : Rare

Repository of type material : AMUGD Cat. No. MF - 482.

Elphidium crispum (Linnaeus) Cushman and Grant

Plate 4, fig.2

Nautilus crispus LINNAEUS, 1758, p. 709 - FICHTEL and MOLL, 1798, p. 40, pl. 4, figs. d-f.

Polystomella crispa (Linnaeus) LAMARCK, 1882, p. 625.

Elphidium crispum (Linnaeus) CUSHMAN and GRANT, 1927, p. 73, pl. 7, figs. 3 a, b. - BHALLA, 1970, pp. 158, 159, pl. 21, figs. 1 a, b et syn. - BHATIA and KUMAR, 1976, p. 242 - BHALLA and NIGAM, 1979, p. 239 - BHALLA and RAGHAV, 1980, p. 288 - BHALLA and LAL, 1985, p. 430 - SHAREEF and VENKATACHALAPATHY, 1988, p. 436, pl. 4, fig. 8.

Description : Test of medium to large size, planispiral, rounded, closely involute, biconvex, biumbonate; periphery acute, with angular keel; chambers numerous, gradually increasing as added; sutures distinct, limbate, slightly raised, gently curved, retral processes distinct, elongate, situated between sutures; umbilical region raised; aperture distinct, multiple, a row of pores arranged at the base of apertural face; wall calcareous; surface smooth, except for ornamentation formed by retral processes.

Dimensions (in mm) : Major diameter 0.51 to 0.78, minor diameter 0.48 to 0.66 and thickness 0.36 to 0.39.

Remarks : Elphidium crispum (Linnaeus) is a widely recorded

and commonly occurring species in shallow turbulent water of different parts of the world which can tolerate a wide range of salinity and temperature fluctuation. It has been reported by Parker (1958) from Mediterranean in 11° to 21°C temperature, 38 to 39‰ salinity range and less than 25 m depth off the coast of Africa. Myers (1943) observed that it is a hardy foraminifera which can remain buried alive from two to three months under an overburden of 1 cm of sediments. According to Murray (1963) E.crispum does not prefer clay substrate and he observed that with decrease in salinity the feeding rate decreases and it can survive in subsaline waters if the temperature is low. From West Coast of India it has been reported by Bhatia (1956), Sethulakshmi Amma (1959), Rocha and Ubaldo (1964 a), Antony (1968), Bhatia and Kumar (1976), Bhalla and Nigam (1979), Bhalla and Raghav (1980), Bhalla and Lal (1985), and Shareef and Venkatachalapathy (1988). While from East Coast of India Bhalla (1968,70) recorded it from Vishakhapatnam and Marina beach,Madras, Ragothaman and Kumar (1985) from Rameswaram coast and Ragothaman and Manivannan (1985) from Mandapam coast. Our specimens are identical to the one described by Bhalla (1970).

Occurrence : Abundant

Repository of type material : AMUGD Cat. No. MF - 483

4.3.7. Family NUMMULITIDAE de Blainville, 1825

Subfamily NUMMULITINAE de Blainville, 1825

Genus NUMMULITES Lamarck, 1801

Nummulites ammonoides (Gronovius)

Plate 4, fig. 3

Nautilus ammonoides GRONOVIUS, 1781, p. 282, pl. 19, figs. 5, 6

Operculina ammonoides (Gronovius) CARPENTER, PARKER and JONES, 1862, p. 310 - BRADY, 1884, p. 745, pl. cx11, figs. 3, 4 - GRAHAM and MILITANTE, 1959, pp. 76, 77 pl. 12, figs. 1, 2, et syn. - ANTONY, 1968, p. 65, pl. 4, fig. 8.

Nummulites ammonoides (Gronovius) -BHALLA and NIGAM, 1979, p. 239 - BHALLA and RAGHAV, 1980,pp. 288-290.

Description : Test of medium to large size, lenticular, planispiral, bilaterally symmetrical, closely coiled; periphery rounded, smooth, carinate; chambers numerous, enlarging gradually as added, sixteen chambers in last coil; sutures distinct, slightly raised, gently curved, bent backward; aperture at the base of apertural face; wall calcareous, perforate; surface smooth.

Dimensions (in mm) : Major diameter 0.63 to 0.76, minor diameter 0.57 to 0.63 and thickness 0.24 to 0.30.

Remarks : Nummulites ammonoides (Gronovius) is a cosmopo-

litan species and occurs abundantly in the present material. X-ray studies by Mayers (1932) on various porcellaneous as well as hyaline species including Nummulites ammonoides have indicated that all have walls composed of calcite.

From West Coast of India Antony (1968) described it from Kerala coast from 22 to 91 m depth range. Bhalla and Nigam (1979) described this species from Calangute beach sand, Goa. Bhalla and Raghav (1980) reported this species from Purakkad beach, Malabar Coast, West Coast of India.

Rao et al. (1970) obtained it from 20 to 183 m depth range from shelf region off Vishakhapatnam, East Coast of India. Specimens in the present material are mostly abraded indicating that they have been subjected to intensive surf action at the beach.

Occurrence : Abundant

Repository of type material : AMUGD Cat. No. MF - 484

Superfamily	ORBITOIDACEA	Schwager, 1876
4.3.8 Family	EPONIDIDAE	Hofker, 1951
Genus	POROEPONIDES	Cushman, 1944

Poroeponides lateralis (Terquem)

Plate 4, fig.6

Rosalina lateralis TERQUEM, 1878, p. 25, pl. 2, fig. 11

Pulvinulina lateralis (Terquem) BRADY, 1884, p. 689, pl. 106, figs. 2, 3.

Eponides lateralis (Terquem) CUSHMAN, 1931, p. 47, pl. 10, fig. 5.

Eponides repandus (Fichtel and Moll) TODD, 1965, pp. 20, 21, pl. 7, figs. 3, 4.

Poroeponides lateralis (Terquem) CUSHMAN, 1944, p. 34, pl. 4, fig. 23 - BHALLA, 1970, p. 160, pl. 21, figs. 6 a, b, et syn. -ROCHA and UBALDO, 1964 a, p. 415, pl. 2, fig. 11, 1964 b, p. 647, pl. 1, figs. 11, 15 - BHATIA and KUMAR, 1976, p. 242 - VENKATACHALAPATHY and SHAREEF, 1976, pp. 378, 379, pl. 1, figs. 5 a, b - BHALLA and NIGAM, 1979, p. 239 - BHALLA and GAUR, 1987, p. 125, pl. 1, fig. 20.

Description : Test of medium to large size, oval shaped, trochospiral, biconvex; periphery entire, carinate; dorsal side evolute with fourteen chambers, enlarging gradually with growth, proloculus small; dorsal sutures distinct, raised,

curved, bent backward, touching periphery, ventral side involute with eight distinct chambers, gradually increasing as added; ventral sutures distinct, depressed somewhat thickened, narrowing towards periphery; apertural face broad and flattened; umbilicus with rather large plug, slightly raised; primary aperture an interiomarginal slit at the base of last chamber, extending from umbilicus to peripheral keel, in addition to rounded aerial pores scattered over apertural face; wall calcareous, perforate; surface smooth.

Dimensions (in mm) : Major diameter 0.57 to 0.84, minor diameter 0.49 to 0.70 and thickness 0.33 to 0.39.

Remarks : Poroeponides lateralis (Terquem) is a world wide recorded species and shows a wide range of variation especially in the shape of its last formed chamber and umbilical region. It occurs frequently in shore sand because of its ability to resist abrasion. However, it has also been found in deep water. Said (1949) recorded it from a depth of 24 to 400 m in the Gulf of Suez and Red Sea.

From East coast of India it has been reported by Bhatia and Bhalla (1959) from Puri beach sand and Bhalla (1968) from Vishakhapatnam beach sand.

From West Coast of India Bhatia (1956) recorded it from Juhu, Chowpatty and Bhogat beaches; Rocha and Ubaldo (1964 a, b) from Gogola, Simbor and Baga beaches; Bhalla and

Nigam (1979) from Calangute beach sand, Goa; Srivastava et al. (1984) from Veraval beach, Saurashtra Coast, and Bhatia and Kumar (1976) described it from Anjidiv island near Karwar at 5-10 m depth, 28° to 31.1° temperature and 33.49 to 35.1‰ salinity range.

Occurrence : Abundant

Repository of type material : AMUGD Cat. No. MF - 485

4.3.9. Family AMPHISTEGINIDAE Cushman, 1927

Subfamily AMPHISTEGININAE Chapman & Parr, 1936

Genus AMPHISTEGINA d'Orbigny, 1826

Amphistegina madagascariensis d'Orbigny

Plate 4, fig. 4

Amphistegina madagascariensis d'ORBIGNY, 1826, p. 304 - TODD, 1965, p. 34, pl. 1, fig. 3, pl. 12, figs. 1-2, et syn. - BHALLA, 1970, p. 160, pl. 21, figs. 7a-c - GUPTA, 1973, p. 781.

Description : Test of medium size, low trochoid, nearly circular, biconvex; periphery rounded, abraded; chambers numerous, enlarging gradually as added; sutures obscure, slightly angled; umbilical area with raised Knobs on both sides; aperture narrow at the base of last chamber; wall calcareous, finely perforate; surface smooth.

Dimensions (in mm) : Major diameter 0.62 to 0.69, minor diameter 0.60 to 0.66 and thickness 0.23 to 0.26

Remarks : Amphistegina madagascariensis d'Orbigny, 1826, is an Indo-Pacific species which prefers a warm shallow water environment and occurs abundantly in Dwarka beach material. According to Todd (1965) Amphistegina madagascariensis varies with environment and in beach and near shore environments the tests are found to be generally thicker with obscure sutures

and are abundant as compared to deep waters.

From Indian waters Bhalla (1970), first of all, reported A. madagascariensis from Marina beach, Madras, East Coast of India. Later, Gupta (1973) described it from lagoonal sediments of Kavaratti Atoll, Laccadives, at a maximum depth of 4 m, 30.6^{o} to 32.5^{o} C bottom temperature and 33 to 53‰ salinity range. Our specimens are almost identical to the one described by Bhalla (1970) and possesses slightly raised umbonal knobs and abraded periphery.

Occurrence : Abundant.

Repository of type material : AMUGD Cat. No. MF - 486

4.3.10	Family	CIBICIDIDAE	Cushman, 1927
Subfamily		CIBICIDINAE	Cushman, 1927
Genus		CIBICIDES	De Montfort, 1808

Cibicides lobatulus (Walker & Jacob)

Plate 4, fig. 8

Nautilus lobatulus WALKER and JACOB, 1798, p. 642, pl. 14, fig. 36 (fide, GRAHAM and MILITANTE, 1959)

Truncatulina lobatulus WILLIAMSON, 1858, p. 660, pl. 92, fig. 10, pl. 93,figs. 1-5, pl. 95,figs. 4,5. - CUSHMAN, 1915, pl. 15, fig. 1

Cibicides lobatulus (Walker and Jacob) - CUSHMAN, 1931, p. 118, pl. 21, figs. 6, 7, 1946, p. 9, pl. 2, figs. 6, 7 - BHATIA, 1956, p. 24, pl. 5, fig. 7 - GANAPATI and SATYAVATI, 1958, pl. 6, figs. 164-166 - ROCHA and UBALDO, 1964 a, p. 415, pl. 3 fig. 1 , 1964 b, p. 647, pl. 1, figs 1, 2. - ANTONY, 1968, pp. 114, 115, pl. 8 figs. 11 a, b - RAO, 1971 a, p. 162, 1971 b, pp. 14, 15, fig. 82 - BHALLA and NIGAM, 1979, p. 239 - BHALLA and LAL, 1985, p. 430 - SHAREEF and VENKATACHALAPATHY, 1988, p. 435 , pl. 3, fig. 12.

Description : Test of medium size, trochospiral, nearly circular, plano-convex; periphery lobulate, with non-porous keel of clear shell material, generally wider in the early part of test; dorsal side nearly flat, evolute, chambers

increasing gradually as added; dorsal sutures rather distinct, slightly curved, limbate, slightly depressed ; ventral side convex, involute, chambers distinct, eight to ten in number, slightly inflated, enlarging gradually as added; ventral sutures distinct, simple, depressed; umbilicus small, shallow, filled with secondary shell material ; aperture interiomarginal, a low arched opening with a narrow lip; wall calcareous, coarsely perforate ; surface smooth.

Dimensions (in mm) : Major diameter 0.48 to 0.51, minor diameter 0.41 to 0.42 and thickness 0.21 to 0.22.

Remarks : Cibicides lobatulus (Walker and Jacob), is a commonly occurring species of shallow marine water and has been reported from different parts of world by many workers. Ganapati and Satyavati (1958) reported this species from Vishakhapatnam coast, East Coast of India at 58 to 104 fathoms depth and 56° to 69° F temperature range.

From West Coast of India, it has been recorded by Bhatia (1956) from Bhogat beach; Rocha and Ubaldo (1964 a, b) from Diu, Gogola, Simbor and Baga beaches; Antony (1969) from Kerala coast at 5 to 100 m depth ranges: Bhalla and Nigam (1979) from Calangute beach, Bhalla and Lal (1985) from Okha beach sand, and Shareef and Venkatachalapathy (1988) from Devgad and Bhatkal islands. However, the specimens in the present meterial are identical to those described by Shareef

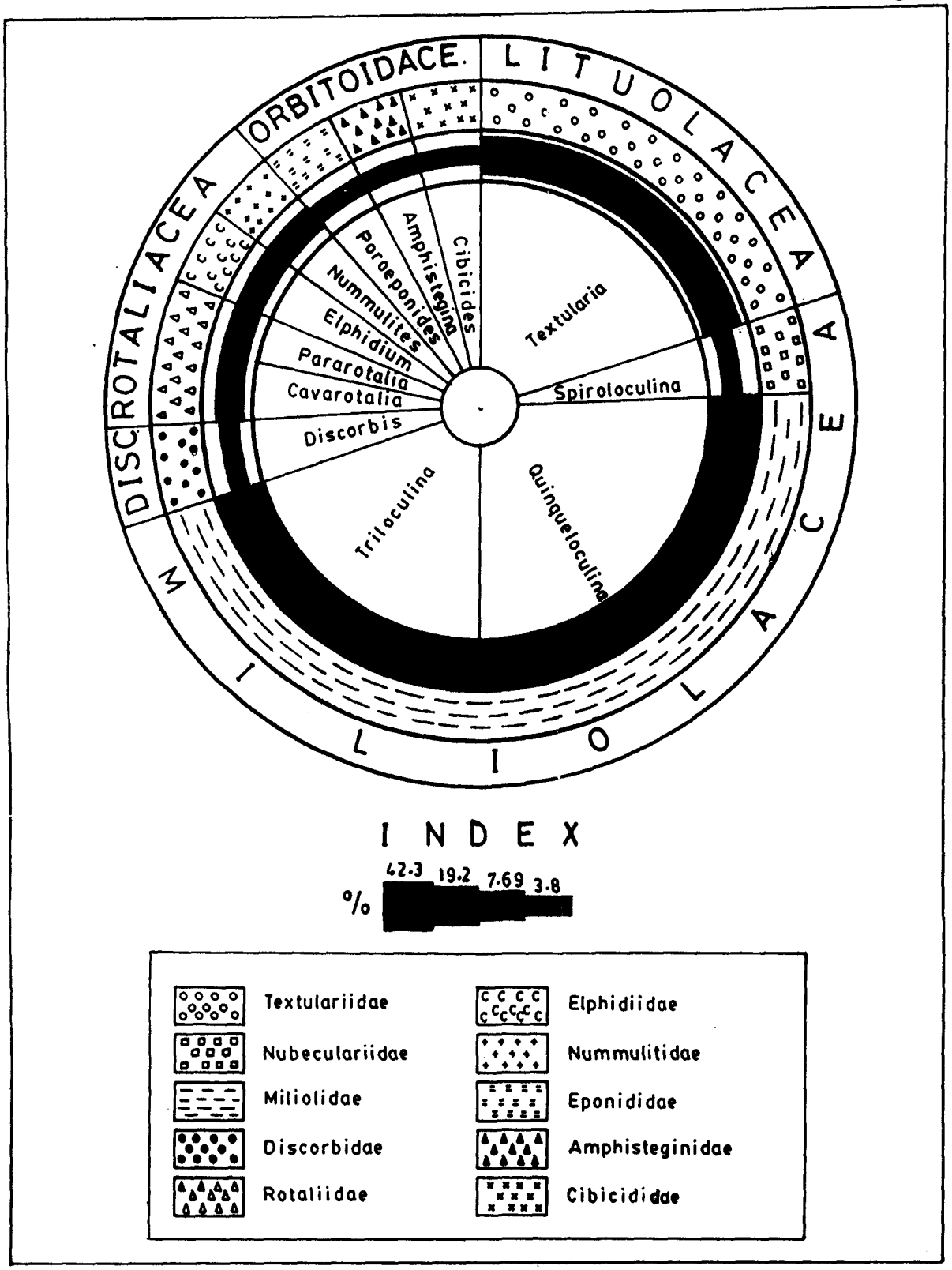
and Venkatachalapathy (1988).

Occurrence : Rare

Repository of type material : AMUGD Cat. No. MF - 487

Text - fig. 5

Text-fig. 5



Composition of foraminiferal assemblage

C H A P T E R - V

COMPOSITION, FREQUENCY DISTRIBUTION AND AFFINITIES OF FORAMINIFERAL ASSEMBLAGE

5.1 Composition of Foraminiferal Assemblage

A total of 2017 specimens of foraminifera were recorded from 10 gram representative material of Dwarka beach, Saurashtra Coast, Gujarat, comprising twenty-six species belonging to ten families. The assemblage is chracterized by both calcareous and agglutinated forms. However, calcareous forms constitute 80.76% of the total foraminiferal assemblage and consist of both perforate and imperforate species. The ratio of agglutinated to calcareous tests is 1:5.2. Family Miliolidae is abundant in terms of number of species. It is represented by eleven species (42.30% of total foraminiferal species) followed by family Textulariidae which is represented by five species (19.2%). Of the remaining species, two each belong to family Rotaliidae and Elphididae (7.69% each) and one each to family Nubeculariidae, Discorbidae, Nummulitidae, Eponididae, Amphisteginidae, and Cibicididae (3.84% each). Text-fig. 5 displays the composition of foraminiferal assemblage of Dwarka beach sand, Saurashtra Coast. However, the foraminiferal assemblage is dominated by species belonging to

genus Quinqueloculina (seven species) followed by genus Textularia (five species)

5.2 Frequency Distribution : The frequency distribution of different foraminiferal species in the Dwarka beach sand, Saurashtra Coast, Gujarat is displayed in Table 1 and is based on the number of specimens counted in a representative ten gram material.

The present assemblage is abundant in Triloculina trigonula, Quinqueloculina pseudoreticulata, Cavarotalia annectens, Pararotalia boltovskoyi, Elphidium crispum, Nummulites ammonoides, Poroeponides lateralis, and Amphistegina madagascariensis, while Quinqueloculina seminulum is common and Textularia foliacea, Quinqueloculina undulose-costata and Triloculina terquemiana are frequent. The rare species in the present assemblage are Textularia agglutinans, T. kerimbaensis, Textularia cf. T. punjabensis, T. rugosa, Spiroloculina indica, Quinqueloculina aff. Q. oculus, Quinqueloculina sulcata, Q. vulgaris, Quinqueloculina sp., Triloculina aff. T. inornata var. longidentata, Triloculina aff. T. unidentata, Elphidium craticulatum, Discorbis sp. and Cibicides lobatulus.

The criterion used for rare, frequent, common, and abundant species are as follows:

Rare (R)	-	upto two specimens
Frequent (F)	-	three to five specimens
Common (C)	-	six to seven specimens
Abundant (A)	-	more than seven specimens

TABLE - 1 : Frequency Distribution of Recent Foraminifera in Dwarka Beach Sand, Saurashtra Coast, Gujarat

Foraminifera	Occurrence
Textularia agglutinans d'Orbigny	Rare
Textularia foliacea Heron-Allen & Earland	Frequent
Textularia aff. T. kerimbaensis Said	Rare
Textularia cf. T. punjabensis Haque	Rare
Textularia rugosa Costa	Rare
Spiroloculina indica Cushman and Todd	Rare
Quinqueloculina aff. Q. oculus d'Orbigny	Rare
Quinqueloculina pseudoreticulata Parr	Abundant
Quinqueloculina seminulum (Linnaeus)	Common
Quinqueloculina sulcata d'Orbigny	Rare
Quinqueloculina undulose-costata Terquem	Rare
Quinqueloculina vulgaris d'Orbigny	Rare
Quinqueloculina sp.	Rare
Triloculina aff. T. inornata d'Orbigny	Rare
Triloculina terquemiana (Brady)	Frequent
Triloculina trigonula (Lamarck)	Abundant
Triloculina aff. T. unidentata d'Orbigny	Rare
Discorbis sp.	Rare
Cavarotalia annectens (Parker and Jones)	Abundant
Pararotalia boltovskoyi Jain and Bhatia	Abundant
Elphidium craticulatum (Fichtel and Moll)	Rare
Elphidium crispum (Linnaeus)	Abundant

Nummulites ammonoides (Gronovius)	Abundant
Poroeponides lateralis (Terquem)	Abundant
Amphistegina madagascariensis d'Orbigny	Abundant
Cibicides lobatulus (Walker and Jacob)	Rare

5.3 Affinities of Foraminiferal Assemblage

The foraminiferal assemblage of Dwarka beach sand, Saurashtra Coast, exhibits affinities with other foraminiferal assemblages described from shore sands or various parts of West and East Coasts of India (Table 2).

5.3.1 Comparison with West Coast Assemblages :

Bhatia (1956) described forty-six species of Recent foraminifera from Juhu, Chowapatty, and Bhogat beaches of West Coast of India. These beaches have following species which also occur in Dwarka beach assemblage.

Juhu : Spiroloculina indica, Quinqueloculina seminulum, Q. undulose-costata, Streblus annectens (=Cavarotalia annectens), and Poroeponides lateralis.

Chowpatty : Quinqueloculina seminulum, Q. undulose-costata, Streblus annectens, and Poroeponides lateralis.

Bhogat : Textularia foliacea, Spiroloculina indica, Quinqueloculina seminulum, Q. undulose-costata, Triloculina terquemiana, Streblus annectens, Elphidium craticulatum, E. crispum, Poroeponides lateralis, and Cibicides lobatulus.

Rocha and Ubaldo (1964a) described fifty-two species of Recent foraminifera from Diu, Gogola and Simbor beaches of West Coast of India. The following species which have been reported from these beaches are also found in the

present assemblage.

Diu : Quinqueloculina undulose-costata, Q.vulgaris, Triloculina terquemiana, T. trigonula, Streblus annectens, Elphidium craticulatum, E. crispum, Poroeponides lateralis and Cibicides lobatulus.

Gogola : Spiroloculina indica, Quinqueloculina undulose-costata, Triloculina trigonula, Streblus annectens, Elphidium craticulatum, E. crispum, Poroeponides lateralis and Cibicides lobatulus.

Simbor : Quinqueloculina undulose-costata, Q. vulugaris, Streblus annectens, Elphidium crispum, Poroeponides lateralis, and Cibicides lobatulus.

In a subsequent publication Rocha and Ubaldo (1964b) reported twenty-fives species of Recent foraminifera from Jampor (Damao) and Baga (Goa) beaches. The following species which were reported from these beaches are also present in Dwarka assemblage:

Jampor (Damao): Elphidium craticulatum and Streblus annectens.

Baga (Goa) : Spiroloculina indica, Quinqueloculina pseudoreticulata, Streblus annectens, Poroeponides lateralis and Cibicides lobatulus.

A fairly rich foraminiferal assemblage comprising thirty-seven species was described by Jain and Bhatia (1978) from Mandvi beach, Kutch. Spiroloculina indica, Quinqueloculina seminulum, Pararotalia boltovoskoyi, Elphidium crispum and Poroeponides lateralis occuring in Dwarka beach assemblage are also present in the Mandvi beach assemblage.

Bhalla and Nigam (1979) reported thirty-six species from Calangute beach sand, Goa. The following species of Calangute beach fauna are also found in the present assemblage: Quinqueloculina seminulum, Q. pseudoreticulata, Q. vulgaris, Triloculina terquemiana, Ammonia annectens (=Cavarotalia annectens), Elphidium craticulatum, E. crispum, Nummulites ammonoides, Poroeponides lateralis and Cibicides lobatulus.

Bhalla and Raghav (1980) described twenty-five species of Recent foraminifera from Cochin, Chellanum and Purakkad beaches of Malabar Coast. Species common to these beaches and the Dwarka beach assemblage are:

Cochin : Ammonia annectens, and Elphidium crispum.

Chellanum : Ammonia annectens, and Elphidium crispum.

Purakkad : Quinqueloculina vulgaris, Ammonia annectens and Elphidium crispum.

Srivastava et al. (1984) described twenty-seven species from Veraval beach sand, Saurashtra Coast, Gujarat. Out of these, the following six species are also present in Dwarka beach assemblage; Quinqueloculina seminulum, Triloculina trigonula, Ammonia annectens, Elphidium craticulatum, E. crispum, and Poroeponides lateralis

Bhalla and Lal (1985) recorded eighteen species of Recent foraminifera from Okha beach sand, Saurashtra coast. Species common to both the assemblages are Textularia foliacea, Spiroloculina indica, Quinqueloculina seminulum, Triloculina trigonula, T. terquemiana, Ammonia annectens, Pararotalia boltovskoyi, Elphidium craticulatum, E. crispum, Poroeponides lateralis and Cibicides lobatulus.

Out of twenty-nine species described by Bhalla and Gaur (1986, 87) from Colva beach sand, Goa, the following are also present in Dwarka beach sand: Textularia foliacea, Quinqueloculina seminulum, Triloculina terquemiana, Cavarotalia annectens and Poroeponides lateralis.

Shareef and Venkatachalapathy (1988) described forty species of Recent foraminifera from beach sand of Bhatkal island and forty-one species from Devgad island. Textularia foliacea, Quinqueloculina pseudoreticulata, Q. seminulum, Q. vulgaris, Triloculina trigonula, Elphidium crispum, and Poroeponides lateralis occur both in Bhatkal

island and Dwarka beach assemblage whereas species common to Devgad island and Dwarka beach are Textularia foliacea, Quinqueloculina pseudoreticulata, Q. seminulum, Q. undulose-costata, Q. vulgaris, Triloculina trigonula, Elphidium crispum, and Poroeponides lateralis.

5.3.2. Comparison with East Coast Assemblages :

Bhatia and Bhalla (1959) described fourteen species of Recent foraminifera from Puri beach sand, Orissa, out of which the following species are also found in Dwarka beach assemblage: Quinqueloculina seminulum, Triloculina trigonula, and Streblus annectens.

Bhalla (1967) reported sixteen species from Vishakhapatnam beach sand. Quinqueloculina seminulum, Triloculina trigonula, T. terquemiana and Poroeponides lateralis occur in both Dwarka beach and Vishakhapatnam beach sand.

Out of fifteen species described by Bhalla (1970) from Marina beach, Madras, Quinqueloculina seminulum, Q. vulgaris, Triloculina trigonula, Ammonia annectens, Elphidium crispum, Poroeponides lateralis, and Amphistegina madagascariensis are also found in Dwarka beach sand.

5.3.3 Discussion :

All the twenty-six species of the foraminiferal assemblage of Dwarka beach, Saurashtra Coast, are benthonic

and belong to typical shallow, warm water environment. Planktonic forms are significantly absent in the present foraminiferal assemblage. A comparative study of foraminiferal species recorded from Dwarka beach sand and those of other beaches on West and East Coasts of India indicates that eight species , viz., Quinqueloculina seminulum, Quinqueloculina vulgaris, Cavarotalia annectens, Elphidium crispum, Poroeponides lateralis, and Amphistegina madagascariensis are common to both West and East Coasts of India. However, eight species, viz., Textularia foliacea, Spiroloculina indica, Quinqueloculina pseudoreticulata, Q. undulose-costata, Pararotalia boltovskoyi, Elphidium craticulatum, Nummulites ammonoides, and Cibicides lobatulus are restricted to West Coast only.

Three species , viz., Textularia agglutinans, Quinqueloculina sulcata and Amphistegina madagascariensis are recorded for the first time from West Coast of India, whereas Textularia aff. T. kerimbaensis, Textularia cf. T. punjabensis, T. rugosa, Quinqueloculina aff. Q. oculus, Triloculina aff. T. inornata, Triloculina aff. T. unidentata are recorded for the first time from Indian waters.

It is observed that Quinqueloculina tropicalis, Asterorotalia trispinosa, Pseudorotalia schroeteriana, Ammonia hozanensis and Dentostomina agglutinans, found on the East Coast, have not been reported from West Coast of India

so far.

Quinqueloculina seminulum, Q. undulose-costata, and Cavarotalia annectens, which are frequent to abundant in occurrence on West Coast show rare occurrence on East Coast of India. Triloculina terquemiana which shows rare to frequent occurrence on West Coast occurs rarely on East Coast, whereas Triloculina trigonula, Elphidium crispum and Poroeponides lateralis are found on both the Coasts and are frequent to abundant in occurrence.

Bhogat and Okha are two important beaches or Saurashtra Coast and Comparison of Dwarka beach assemblage with the faunas from these two beaches indicates that out or thirty species from Bhogat and eighteen species from okha only ten and eleven species respectively are common to Dwarka beach assemblage. Comparison with Diu (thirty-four species) Gogola (thirty-nine species) and Simbor (twenty-nine species) beaches indicates that only nine, eight and six species respectively which are found on these beaches also occur on Dwarka beach and correlation of Dwarka and Veraval beach assemblages (twenty-seven species) shows that only six species are common to both the beaches.

Total Foraminiferal Number (TFN) was counted in the present assemblage which is 288 in 10 grams or beach material. TFN depends upon prevailing ecological conditions

of the coastal waters. It is a well known fact that foraminifers found in beach sand do not live on beach but thrive in coastal waters very near to the shore line and washed into the beach region by waves action (Bhalla, 1970). TFN of beach assemblage may, therefore, provide some clue to the prevailing ecological condition of the near-shore coastal waters.

Bhalla and Nigam (1980), while investigating the foraminiferal fauna of various beaches in Goa, observed a fairly high TFN (7500 in 2 gram material) at Velsao beach as compared to Colva (TFN, 307) and Calaugute (TFN, 480). On this basis they suggested that while Colva and Calangute are 'clean' beaches, coastal water of Velsao beach is polluted due to effluent discharged from nearby Zuari Agro Chemical factory. Moreover, tests of various species, especially those belonging to genus Ammonia exhibit certain morphological abnormalities such as abnormal growth of test and distortion in chambers.

During a study of beach foraminifers of Malabar Coast, Bhalla and Raghav (1980) have observed that Coachin and Purakkad beaches show a low TFN. (280 and 188 respectively per 20 gram material) while Chellanum beach exhibits a higher TFN (1598 per 20 gram). According to these authors the low TFN of Coachin and Purakkad is due to discharge of fresh water from rivers which meet the Arabian

Sea in the vicinity of Cochin and Purakkad beaches, thus lowering the salinity of near coastal water and, in turn, prevent free and normal growth of foraminifera whereas Chellanam beach is free from such interference resulting in a higher TFN in comparison to other two beaches.

In the Dwarka beach assemblage a fairly low TFN per 10 gram of material was counted (TFN, 288) which suggests that Dwarka is a relatively 'clean' beach, free from marine pollutants. This is also supported by absence of any sign of abnormal growth of test as well as distortion in chambers. Moreover, the ecological factors which control the distribution of foraminifera in Dwarka coast appears to be dominated by salinity. This may be inferred in view of the fact the Gomti River joins the Arabian Sea near Dwarka, (Pl. 1,fig.2) discharging its load of fresh water and lowering the salinity of the costal water.

5.3.4 Zoogeographic Affinity of Dwarka Beach Assemblage and Foramgeographical Provinces of Indian Ocean :

Cushman (1950) divided the Recent warm water foraminiferal assemblage of the world into four main foramgeographical provinces namely Mediterranean, West Indian, East African and Indo-Pacific. According to him the entire West Coast of India and small portion of southern part of East coast belong to East African Province whereas the rest of East Coast of India and almost entire Bay of Bengal

fall under the zone formed by mixing of East African and Indo-Pacific Provinces. This "mixed zone" extends from the Bay of Bengal to Great Australian Bight and forms a boundary between the two provinces. Towards the east of this zone, lies the Indo-Pacific Foramgeographical Province. This View was also supported by Bhalla (1968,70) and Boltovoskoyi and Wright (1976).

However Bhalla's (1968,70) contention that the East and West Coasts of India belong to different foramgeographical provinces is contradicted by Bhatia and Kumar (1976) and Jain and Bhatia (1978). According to these authors the West and the East Coasts of India could not be assigned to different foramgeographical provinces, a view also supported by Srivastava et al. (1984) and Shareef and Venkatachalapathy (1988).

The foraminiferal fauna of Dwarka beach includes as many as eight cosmopolitan species and seven Indo-Pacific species, viz., Textularia foliacea, T. kerimbaensis, Quinqueloculina pseudoreticulata, Triloculina terquemiana, Cavarotalia annectens, Elphidium craticulatum, and Amphistegina madagascariensis. A number of other workers have also observed the presence of considerable number of Indo-Pacific forms in the foraminiferal assemblages of the West Coast of India (Bhatia, 1956; Rocha and Ubaldo, 1964 a,b, ; Rao, 1970-71; Siebold, 1975; Bhatia and Kumar, 1976 ; and Shareef and

Venkatachalapathy (1988).

Jain and Bhatia (1978) while discussing the zoogeographic affinity of the foraminiferal fauna of Mandvi beach, Kutch found that a large number of species belongs to Indo-Pacific Zoogeograhic Province.

Srivastava et al. (1984) who studied Recent foraminifera from beach sand near Verwal, Saurashtra Coast, observed that a considerable number of species belongs to Indo-Pacific Province with elements of East African and other provinces also.

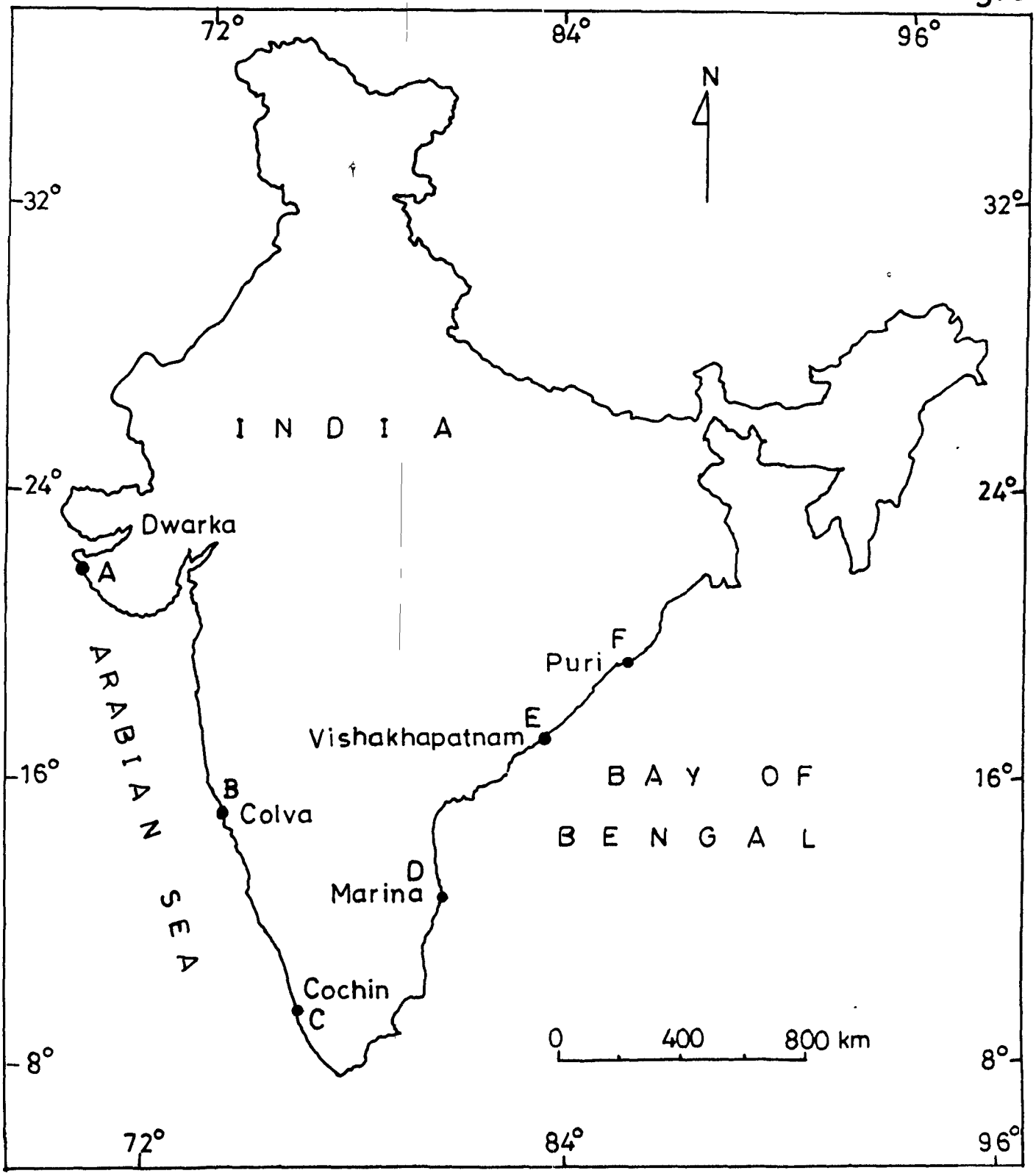
Similarly, Shareef and Venkatachalapathy (1988) have also reported that most of the species recorded from Bhatkal and Dev gad islands, West Coast of India, exhibit a greater affinity to the Indo-Pacific Zoogeographic Province.

However, the controversy that whether West and East Coasts of India belong to same or different foramgeographical province, still exist. Bhalla and Nigam (1988) tried to solve this problem statistically by carrying out Q-mode cluster analysis (Weighted Pair Group Method -WPGM) of thirty species of foraminifera from six sandy beaches, three each from West and East Coasts. According to these authors (op. cit.), East and West Coasts of India belong to two different faunal realms as it is evident from their dendogram.

An attempt is made here to carry out Q-mode cluster

Text - fig. 6

Text-fig.6



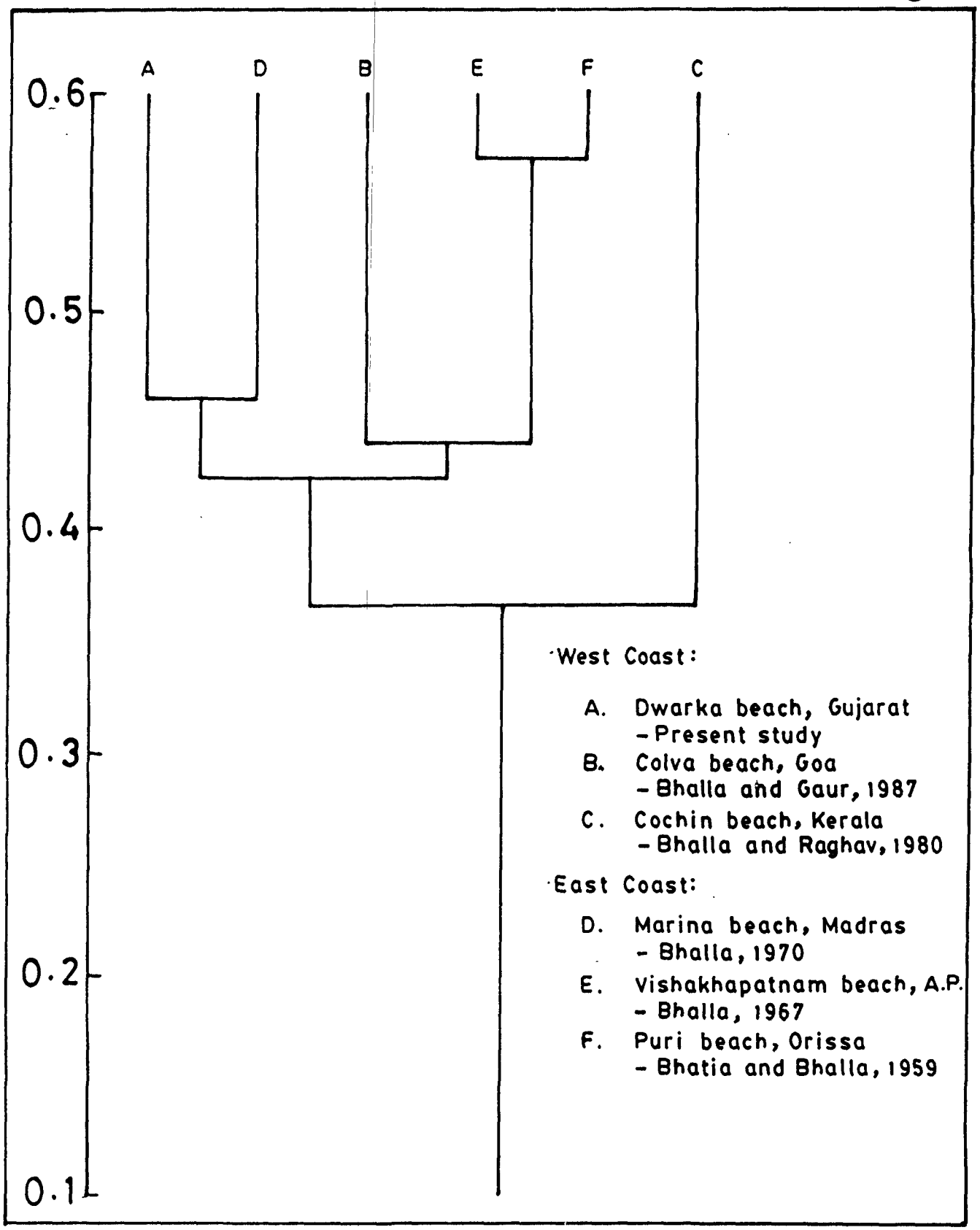
Map showing locations used in cluster analysis

analysis using WPGM method of Sokal and Sneath (1963) taking six beaches from the Indian coast (three from West Coast, viz., Dwarka, Colva and Cochin and three from East Coast, viz., Marina, Vishakhapatnam and Puri) (Text-fig. 6). The West Coast beaches selected for the present analysis are different from those considered by Bhalla and Nigam (1988) in their cluster analysis and more or less represent the entire West Coast. However, the East Coast beaches are the same as taken by Bhalla and Nigam (op. cit.) in their study as other beaches of East Coast of India have not been explored so far for their Recent foraminiferal content. Simpson's coefficient (1961) as against Jaccard's coefficient used by Bhalla and Nigam (1988) has been employed for calculating faunal similarity between two assemblages. As shown by Fallaw (1979) Simpson's coefficient has an advantage over Jaccard's coefficient in the sense that if there is a considerable difference between the total number of species in the two assemblages being compared Jaccord's coefficient will given misleading results.

Therefore, with the help of Simpson's coefficient (C/N_1) where C represents number of species common to two beaches being compared and N_1 represents the beach having smaller number of species, matrix is prepared and on this matrix Q-mode cluster analysis was carried out (WPGM). For calculating successive matrices, Spearman's sums of variable

Text - fig. 7

Text-fig. 7



Dendogram showing result of Q-mode cluster analysis

formulae were used (Appendix - II).

A glance at the dendogram (Text-fig. 7) constructed with the help of Q-mode cluster analysis clearly reveals that the six beaches belonging to West and East Coasts could not be grouped into separate clusters, thus suggesting that West and East Coasts of India do not belong to different foramgeographical provinces.

In view of the above discussion, it could be inferred that the foraminiferal fauna of both the West and East Coasts could not be distinguished separately and probably they belong to "mixed zone" of Cushman (1950) and the entire West Coast of India may be included in this "mixed zone" (Text-fig 8). However, additional data from other beaches of the Indian coast, especially the East Coast, which has not been explored extensively, are required for more comprehensive statistical treatment which will help in arriving at a more definite conclusion regarding the foramgeographical affinity of Recent foraminifera of the Indian coast.

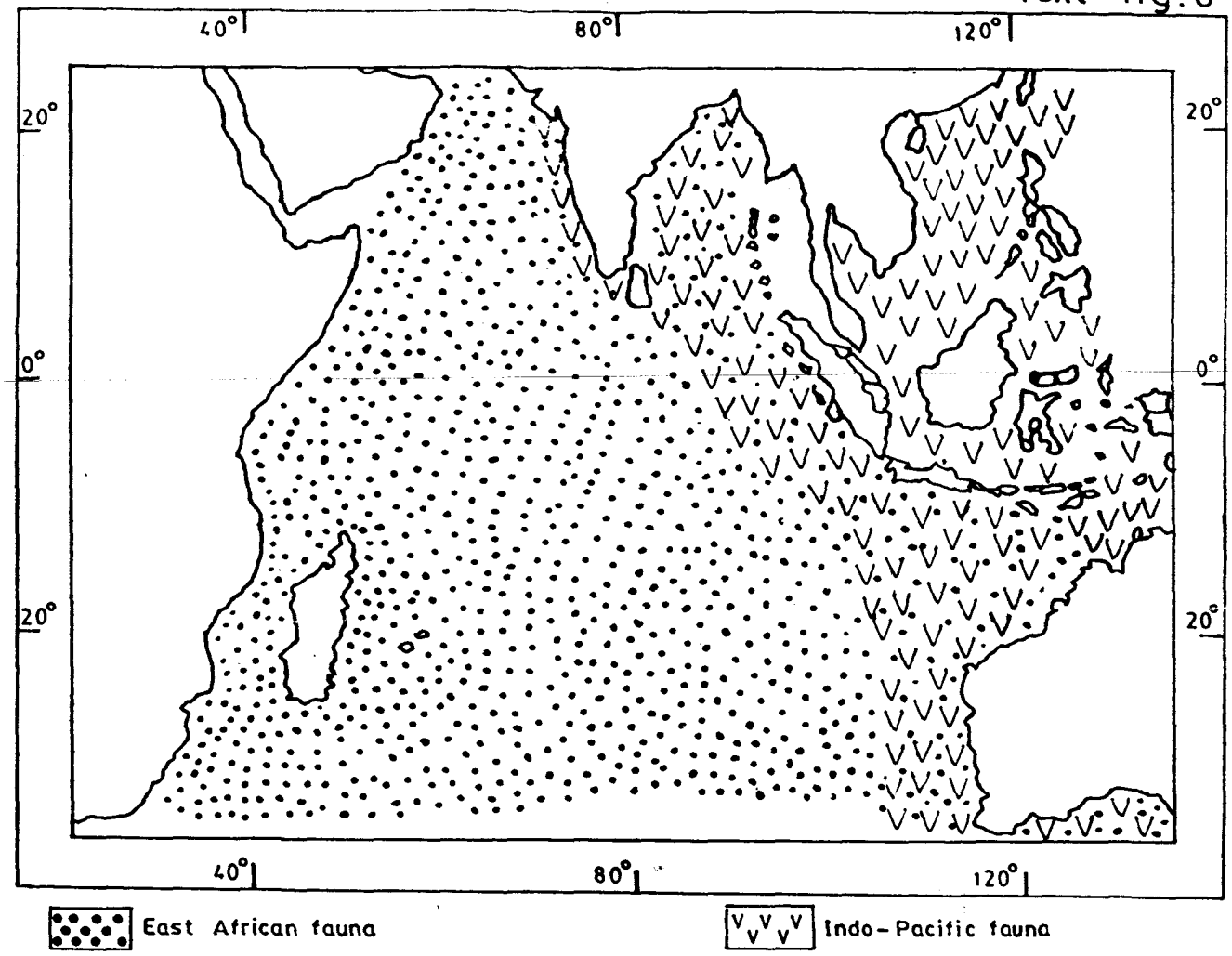
5.4 Conclusion

The following conclusions may be drawn from the above discussion :

1- All the foraminiferal species of Dwarka beach assemblage are benthonic and belong to shallow warm water environment.

Text - fig. 8

Text-fig. 8



Foramgeographical provinces of Indian Ocean showing the extention of "mixed zone" of Cushman (1950)

Planktonic and cold water forms are significantly absent in the present assemblage.

ii- West Coast of India has a prolific foraminiferal population as compared to the East Coast.

iii- West Coast of India is relatively rich in number of foraminiferal species (high TSN) in comparison to the East Coast.

iv- Dwarka beach appears to be a 'clean' beach with coastal water free from marine pollutants. This is evident from an appreciably low TFN and absence of any sign of abnormal growth in foraminiferal tests and distortion in chambers.

v- The distribution of foraminifera at Dwarka beach is controlled by ecological factors in which salinity appears to play a dominant role.

vi- Dwarka foraminiferal assemblage includes as many as eight cosmopolitan and seven Indo-Pacific species and a Q-mode cluster analysis carried on six beaches of West and East Coasts of India including Dwarka indicates that they do not belong to different foramgeographical province. In view of this and observations made by some other workers, it is suggested that the entire West Coast as well as East Coast of India belong to the "mixed zone" of Cushman.

Summary

A total of twenty-six species of Recent foraminifera beloning to ten families have been identified from Dwarka beach sand, Saurashtra Coast, Gujarat. All the species are benthonic and the assemblage belongs to shallow warm water environment. The present assemblage is characterised by both calcareous and agglutinated forms. The former consists of both perforate and imperforate species. Family Miliolidae is abundant in terms of number of species (42.30% of total foraminiferal species). However, the Dwarka beach assemblage is dominated by the genus Quinqueloculina (seven species).

Three species, viz., Textularia aggulutinans, Quinqueloculina sulcata and Amphistegina madagascariensis are recorded for the first time from beach fauna of the West Coast of India. Moreover, Textularia aff. T. kerimbaensis, Textularia cf. T. punjabensis, Textularia rugosa, Quinqueloculina aff. Q. oculus, Triloculina aff. T. inornata, and Triloculina aff. T. unidentata are reported for the first time from India waters.

Variation in shape, size and total number of chambers has been observed in Pararotalia boltoskoyi and is worked out statistically as a prolific population of this species is present in the Dwarka beach assemblage.

A fairly low TFN (280/10 gram of material) is observed in the present assemblage which suggests that Dwarka is a relatively 'clean' beach where salinity appears to play an important role in the distribution of foraminifera.

Comparative study of beach assemblages from West and East Coast of India indicates that the West Coast has a prolific foraminiferal fauna as compared to the East Coast of India.

Cluster analysis carried out on six beaches, three each from West and East Coast of India, suggests that they do not belong to different foramgeographical provinces but are part of the "mixed zone" of Cushman (1950). On the basis of cluster analysis and presence of a considerable number of Indo-Pacific species in the present assemblage, it is suggested that the entire West Coast of India may be included in "mixed zone" of Cushman.

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Appendix-I Test Measurements of Pararotalia boltovoskovi Jain and Bhatia, 1978

Specimen No.	Major diameter (in mm)	Minor diameter (in mm)	Thickness (in mm)	Size of Prolo-culus (in mm)	Total No. of cham-bers	No.of Cham-bers at periphery
1	.59	.54	.35	.045	21	9
2	.45	.41	.30	.037	18	9
3	.53	.44	.27	.052	18	8
4	.31	.41	.21	.675	20	9
5	.56	.47	.26	.06	19	9
6	.44	.40	.26	.052	19	9
7	.50	.45	.27	.033	21	9
8	.48	.44	.27	.061	17	8
9	.45	.40	.24	.049	16	8
10	.47	.42	.27	.055	16	8
11	.48	.45	.29	.028	20	9
12	.48	.42	.35	.018	18	8
13	.47	.44	.29	.054	17	9
14	.47	.42	.27	.066	17	9
15	.57	.51	.30	.046	20	9
16	.48	.44	.29	.034	20	9
17	.50	.44	.30	.049	17	8
18	.56	.44	.27	.018	18	9
19	.44	.36	.24	.06	16	8
20	.42	.24	.24	.034	17	9
21	.45	.47	.33	.03	16	8
22	.41	.35	.26	.037	16	9
23	.43	.38	.26	.045	18	9
24	.54	.51	.30	.057	20	9
25	.50	.42	.27	.051	17	9
26	.53	.50	.27	.03	18	9
27	.51	.45	.27	.055	16	8
28	.54	.45	.29	.058	15	7
29	.51	.45	.20	.036	21	9
30	.62	.53	.33	.048	20	9
31	.50	.45	.28	.03	16	8
32	.56	.48	.30	.06	15	9
33	.59	.53	.29	.034	19	9
34	.51	.44	.30	.045	20	9
35	.42	.36	.23	.033	15	8
36	.48	.45	.24	.03	17	9
37	.47	.50	.33	.045	21	9
38	.39	.36	.24	.054	13	8
39	.47	.42	.26	.045	15	9
40	.51	.44	.27	.03	18	9
41	.50	.45	.26	.036	20	8
42	.48	.45	.24	.037	19	9
43	.42	.39	.26	.03	17	9
44	.45	.42	.29	.045	18	8
45	.45	.42	.27	.045	18	8
46	.51	.44	.26	.048	17	8
47	.57	.45	.27	.045	17	8
48	.45	.45	.26	.034	19	9
49	.44	.42	.27	.057	18	8
50	.48	.42	.23	.06	17	8
51	.48	.41	.24	.06	18	8
52	.48	.44	.29	.045	21	10
53	.50	.44	.24	.052	17	9
54	.45	.39	.27	.06	14	9
55	.51	.45	.26	.03	20	9
56	.60	.54	.27	.048	22	9
57	.48	.42	.23	.06	15	9
58	.48	.45	.30	.046	16	8
59	.48	.44	.20	.051	16	9
60	.54	.45	.24	.045	19	8
61	.54	.51	.30	.06	22	9
62	.66	.54	.30	.015	23	10
63	.60	.53	.29	.054	21	9
64	.54	.45	.27	.03	19	9
65	.51	.47	.27	.036	20	8
66	.50	.45	.27	.06	17	8
67	.48	.42	.26	.022	19	8
68	.41	.38	.23	.075	17	8
69	.50	.44	.27	.03	18	9

Appendix-II

Matrix - I

	A	B	C	D	E	F
A	X	.192	.142	.466	.312	.285
B	.192	X	.428	.266	.431	.357
C	.142	.428	X	.357	.214	.141
D	.466	.266	.357	X	.333	.357
E	.312	.431	.214	.333	X	.571
F	.285	.357	.141	.357	.571	X

Matrix - II

	A'	B	C	E'
A'	X	.267	.291	.424
B	.267	X	.428	.444
C	.291	.428	X	.200
E'	.424	.444	.200	X

A' = A + D

E' = E + F

Matrix - III

	A'	C	E"
A'	X	.291	.426
C	.291	X	.375
E"	.426	.375	X

E" = E' + B

Matrix - 4

	A"	C
A"	X	.367
C	.367	X

A" = A' + E"

For calculating successive matrices following formulae were used :

$$rqQ = \frac{\square\, qQ}{(q+2\,\triangle q)\ (Q+2\,\triangle Q)}$$

where $\square qQ$ is a sum of all correlations between member of one group with the other group, $\triangle q$ is the sum of all correlations between members of the first group, $\triangle Q$ is a similar sum between members of second group, q is the number of OTU'S in group 1 and Q the number of OTU's in group 2, and

$$rq = \frac{rq}{(q+2\,\triangle q)}$$

where the numerator refers to the sum of all the correlations of single OTU with members of cluster.

PLATE - 1

Fig. 1 A panoramic view of Dwarka beach looking north

Fig. 2 Gomti river meeting Arabian Sea, view looking west

Plate 1

Fig. 1

Fig. 2

EXPLANATION OF PLATE - 2

(All are scanning electron micrographs)

1. Textularia agglutinans d'Orbigny
   side view x 56

2. Textularia aff. T. kerimbaensis Said
   side view x 64

3. Textularia foliacea Heron-Allen and Earland
   side view x 67

4. Textularia cf. T. punjabensis Haque
   side view x 63

5. Textularia rugosa Costa
   side view x 52

6. Spiroloculina indica Cushman and Todd
   6a, side view x 55; 6b, apertural view x 95

7. Quinqueloculina seminulum (Linnaeus)

   7a, side view x 56; 7b, apertural view x 59

8. Quinqueloculina aff. Q. oculus d'Orbigny

   8a, side view x 43; 8b, apertural view x 94

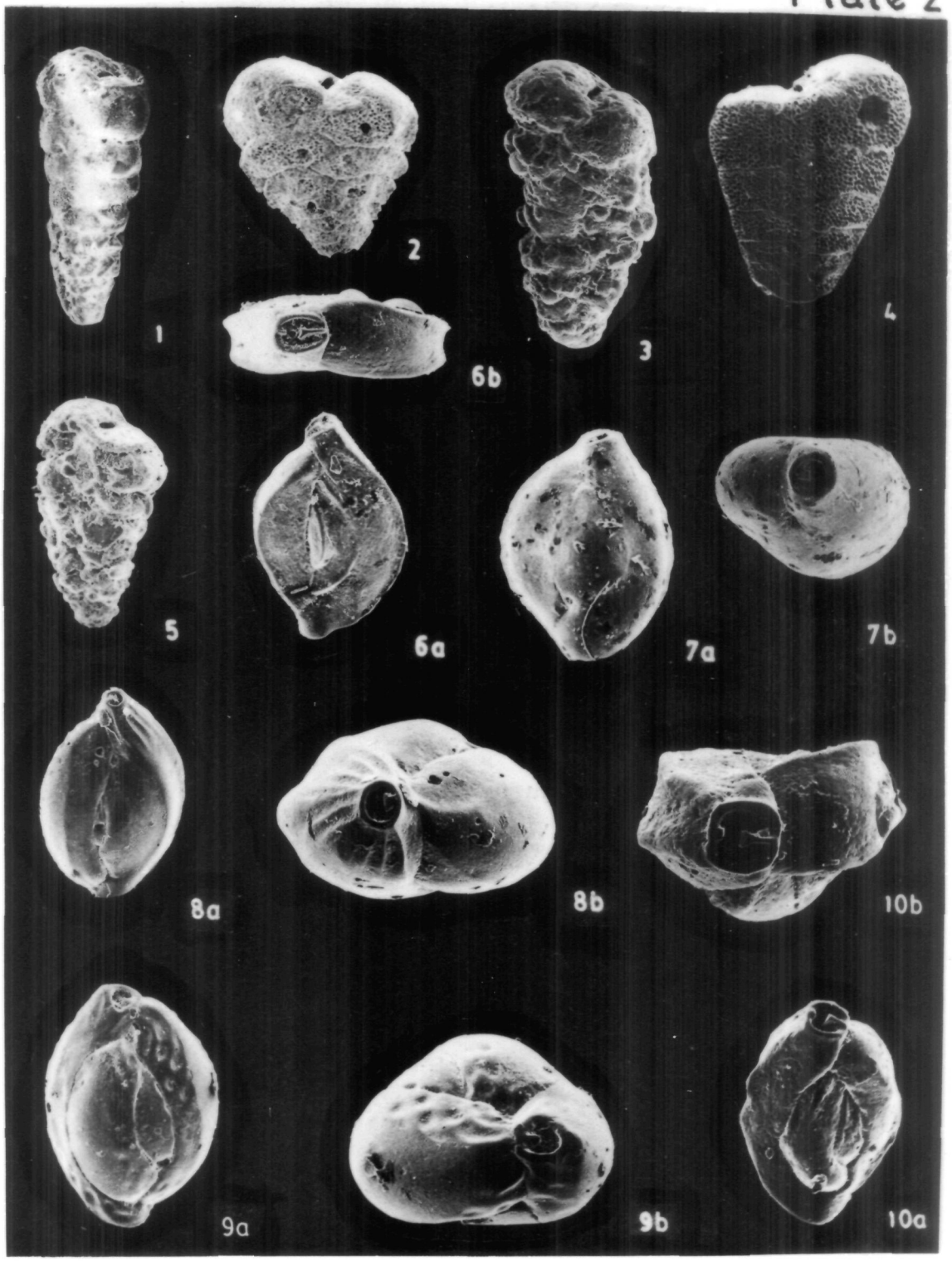
9. Quinqueloculina pseudoreticulata Parr

   9a, side view x 59; 9b, apertural view x 91

10. Quinqueloculina sulcata d'Orbigny

    10a, side view x 71; 10b, apertural view x 143

Plate 2



EXPLANATION OF PLATE - 3

(All are scanning electron micrographs)

1. *Quinqueloculina vulgaris* d'Orbigny

   1a, side view x 71; 1b, apertural view x 120

2. *Triloculina* aff. *T. unidentata* d'Orbigny

   2a. side view x 60; 2b, apertural view x 59

3. *Quinqueloculina* sp.

   3a, side view x 51; 3b, apertural view x 91

4. *Triloculina* cf. *T. inornata* var. *longidentata* Brady

   4a, side view x 61; 4b, apertural view x 86

5. *Triloculina terquemiana* (Brady)

   5a, side view x 65; 5b, apertural view x 74

6. *Triloculina trigonula* (Lamarck)

   6a, side view x 53; 6b, apertural view x 69

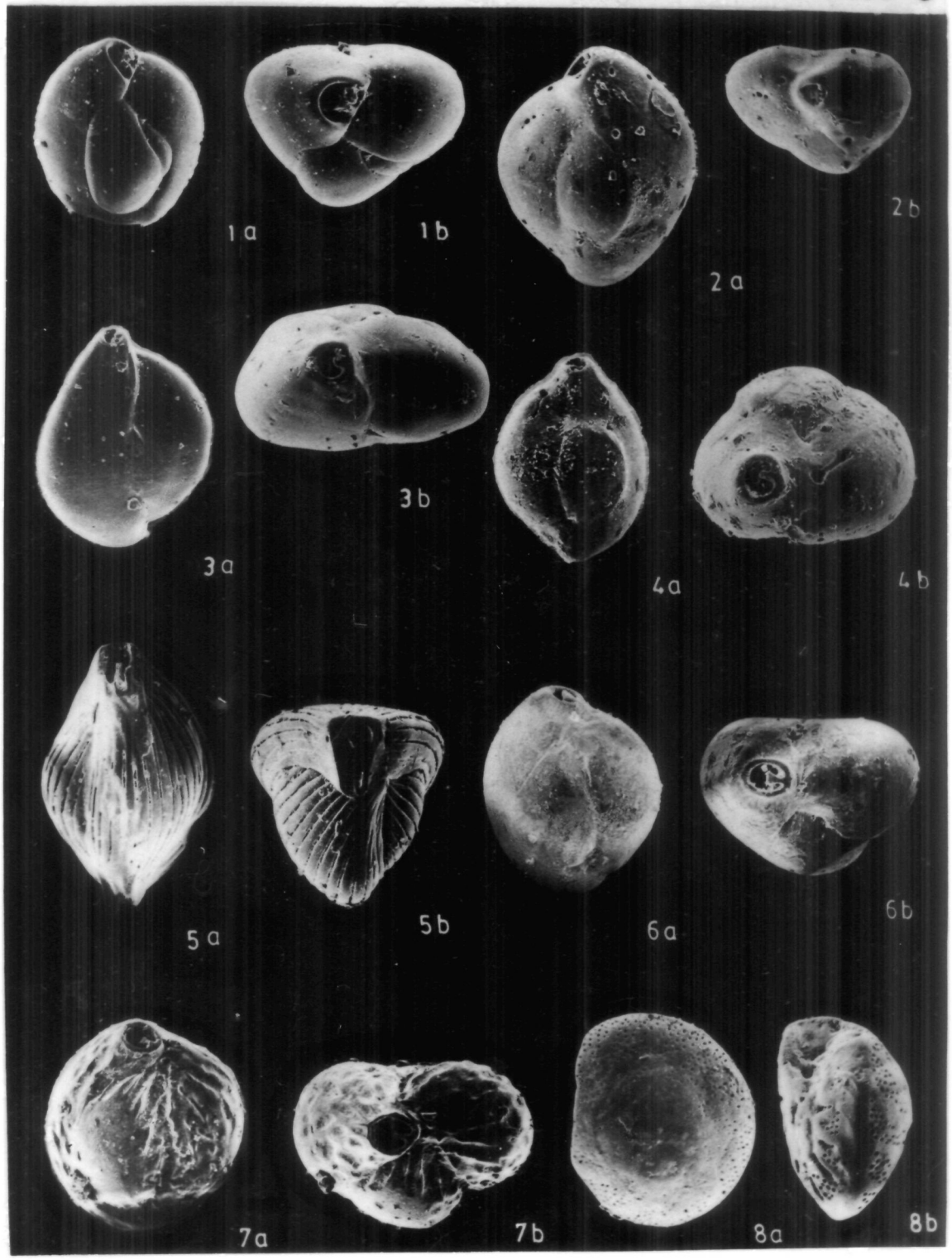
7. *Quinqueloculina undulose-costata* Terquem

   7a, side view x 63; 7b, apertural view x 87

8. *Discorbis* sp.

   8a, dorsal view x 76; 8b, apertural view x 56

Plate 3



EXPLANATION OF PLATE - 4

(All are scanning electron micrographs)

1. Elphidium craticulatum (Fichtel and Moll)

   1a, side view x 47; 1b, apertural view x 35

2. Elphidium crispum (Linnaeus)

   2a, side view x 44; 2b, apertural view x 30

3. Nummulites ammonoides (Gronovius)

   3a, side view x 47; 3b, apertural view x 32

4. Amphistegina madagascariensis d'Orbigny

   4a, side view x 52; 4b, apertural view x 25

5. Pararotalia boltovoskoyi Jain and Bhatia

   5a, dorsal view x 66; 5b, ventral view x 70;

   5c, apertural view x 61

6. Poroeponides lateralis (Terquem)

   side view x 47

7. Cavarotalia annectens (Parker and Jones)

   7a, dorsal view x 49; 7b, ventral view x 45

8. Cibicides lobatulus (Walker and Jacob)

   8a, ventral view x 80; 8b, dorsal view x 76

Plate 4